A CAHNERS PUBLICATION
FEBRUARY 5, 1975

Kevin!

11 APR 1975

2 86days.

EDN

EXCLUSIVELY FOR DESIGNERS AND DESIGN MANAGERS IN ELECTRONICS

Low cost DMM's: what they should be and do

Designer's guide to: Transformer applications

Autointeractive computer graphics simplifies pc board design

AUBLAO 020 360 0002 02 &&
N R 0476 &&
BAYLISS ELECTR PTY LTD
14 16 COTTAGE STR
BLACKBURN VIC AUSTRALIA

BergLance™ Wire-Wrapping Posts give a classic performance on the Lowrey Organ.

The BergLance System assures rapid staking of miniature thru-lugs for solid or stranded wire terminations. It's an approach that offers high quality and reliability . . . and is economical, too.

Lowrey likes it, and has used millions of BergLance posts throughout the past decade. Lowrey has found it can rely on Berg Electronics . . . to supply the product and the application machines that precisely meet its interconnection needs.

Berg is experienced. We read interconnection needs like Lowrey reads music. We have the products, the background and the back-up to do the job. Your job. Let's work on it, together. Berg Electronics, Division, E. I. du Pont de Nemours & Co., New Cumberland, Pa. 17070—Phone (717) 938-6711.

DU PONT REG. U. S. PAT OFF. **BERG ELECTRONICS**

For more information, Circle No. 1

We serve special interests—yours!

FEBRUARY 5, 1975
VOLUME 20, NUMBER 3

EDN

EXCLUSIVELY FOR DESIGNERS AND
DESIGN MANAGERS IN ELECTRONICS

DESIGN NEWS

Now you see through it—now you don't 14

Latest study projects electronic sales to more than double by 1980...Advanced system developed for toll-collection operations...Lasers put test dummies precisely in their proper place...Physicists use Josephson junctions to directly measure laser frequency.

DESIGN FEATURES

Simplify pc design with autointeractive computer graphics... 22

Take some CAD, a little automatic drafting, add a dash of human judgement and mix well. Then watch your time and cost hit a new low.

Low-cost DMM's—two views on what they should be and do 28

By their very nature, under-$200 DMM's offer limited accuracy. But they shouldn't stint on safety or be inconvenient to operate.

Designer's Guide to: Audio and converter transformers 33

To get the most out of the versatile magnetic transformer, textbook theory must be closely coupled with updated practical information.

CMOS: Opportunities unlimited 41

Maximum benefit is obtained from CMOS logic when the designer understands some of the generic properties of this family.

Designer's Guide to: EMI shielding, Part 1 47

Users and designers of electrically powered equipment must now consider EMI implications and be ready to counteract problems.

EDN DESIGN AWARDS. 54

Opto-isolators switch high-voltage dc current...X-Y oscilloscope displays hysteresis loop of any core. . .Extend precision rectifier action to very low signals. . . . Programmable logic circuit has versatile outputs.

PROGRESS IN PRODUCTS

Full-function 100-MHz counter challenges the field. 58

Portable cassette system gets people out of the data stream...DPM is first of type to measure true rms value of any ac waveform.

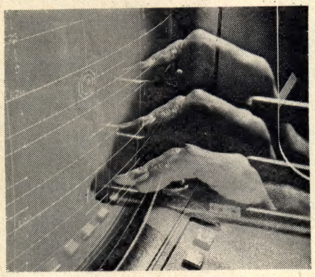
DESIGN PRODUCTS

Semiconductors...60 **Equipment...62** **Component/Materials... 66**
Computer Products...70 **Circuits...74**

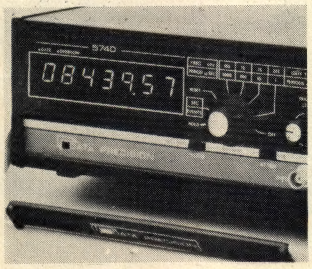
DESIGN DEPARTMENTS

The Editor's Column . . . 7 **Literature . . . 76** **Signals and Noise . . . 79**

Ceramic window. . . pg. 14



Computer graphics pg.22



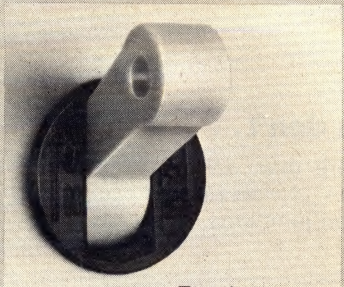
100-MHz counter . . pg.58

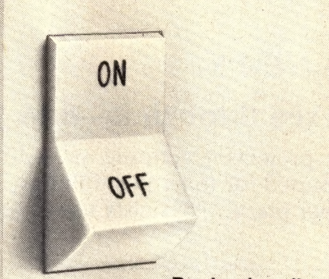
COVER

With a wave of a hand (holding a light pen), sophisticated printed circuits are designed the fast and easy way. Digital Equipment Corporation, Maynard, MA supplied our colorful cover photo. Story begins on pg. 22.

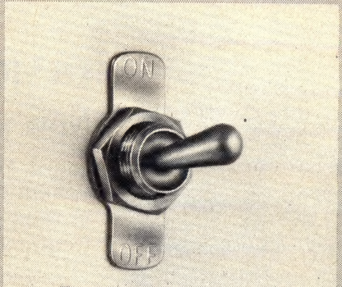
BPA ☆ABP

© 1975 BY CAHNERS PUBLISHING CO., INC. ALL RIGHTS RESERVED. Norman L. Cahners, Chairman of the Board; Saul Goldweitz, President; H. V. Drumm, Executive Vice President/Magazines; Ned Johnson, Senior Vice President/Magazines. EDN (formerly Electrical Design News) is published semi-monthly. Editorial, Advertising offices, 221 Columbus Ave., Boston, Mass. 02116 (617) 536-7780. Subscription offices, 270 St. Paul St., Denver, Colo. 80206 (303) 388-4511. Printed at 85 W. Harrison St., Chicago, Ill. 60605. Controlled circulation postage paid at Chicago, Ill. Send form 3579 to Subscription office. EDN is circulated to electronic design engineers and engineering managers in electronic OEM industries. Plants having more than twenty employees and manufacturing electronically operated or controlled equipment of their own design are considered part of this industry. Engineers in such plants responsible for specification of components, materials and test equipment for electronic application may receive EDN without charge. Completed qualification form and company letterhead *required*. Subscriptions to others in continental United States, $2 per copy. $20 per year. Send requests for qualification forms and changes of address to subscription office in Denver, Colo.


Toggle
Series JA, JB

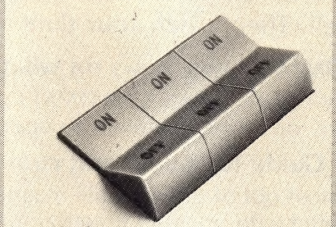


Rocker handle
Series JC

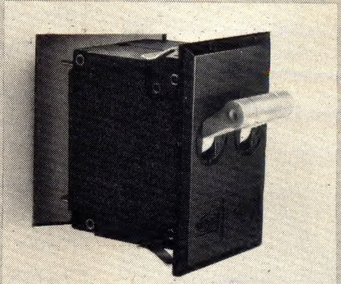


Environmentally sealed
Series JE

Pushbutton
Series JD



Multipole companion-trip
Series JA, JB, JC


Snap-In installation
Series JB

UP FRONT.

That's where Heinemann Type J breakers look best on your equipment.

If a circuit breaker looks this good, why not put it on your equipment's front panel, where it can double as a power switch? It's an ingeniously simple way to cut component and assembly costs.

To meet the widest possible range of application requirements, Type J breakers are offered in any integral or fractional current rating from 0.020 to 30 amp at 240V 60Hz or 400Hz, or 65V DC. With a choice of four time delays and seven special-function internal circuits. With quick-on or screw terminals. And in one, two, three, or four poles.

What about delivery? Well, we now have a Quick-Draw procurement program, under which the most frequently specified Series JA breakers are stocked for shipment within a few days of your order, sometimes overnight.

One final point. Though Heinemann Type J breakers are modestly priced, please don't confuse them with breakers of other types. All Heinemann breakers operate on a totally different, hydraulic-magnetic principle that permits close-tolerance protection with complete freedom from nuisance tripping and other ambient temperature effects. To this day, they're the only circuit breakers good enough to be covered by a five-year warranty.

We'd like you to have our 16-page Bulletin J-3333, which will tell you almost everything you need to know about these breakers. Get it from your nearby Heinemann representative or Heinemann Electric Company, Trenton, NJ 08602. Phone (609) 882-4800.

HEINEMANN
We keep you out of trouble.

For more information, Circle No. 2

© Heinemann

5763

Gates introduces the future in energy cells.

There's now a new energy source that's a superb alternative: Rechargeable, sealed lead-acid batteries from Gates.

We call these batteries the future in energy cells. And for good reason.

They have all the product advantages you need plus economic advantages that may well give a new dimension to your product pricing.

Advantages: Gates Energy Cells are as compact as nickel cadmium or gelled type cells. And they are completely sealed, so that no acid vapor can leak out (they also include a self-sealing vent for extra safety). Gates Energy Cells provide low internal impedance for high discharge rates (more than 100 amps from the D cell and 200 amps from our X cell for short periods of time). And can be operated or stored in any position.

Gates Energy Cells offer great packaging flexibility. In fact, our individual cell availability allows you to choose your own specific voltage (in 2-volt increments) and current, as well as configuration.

Just as important as what Gates Energy Cells have to offer is what they don't have to offer. Like outgassing problems. Or cell reversal. Or "memory" problems.

Because Gates Energy Cells are made from low-cost materials that are readily available, they're very high in watt-hr. per dollar value. Which means that if you specify them, you'll probably save your company more than a few dollars. And make yourself into something of a hero in the bargain.

To find out more about the future in energy cells, circle our reader service number or write us. We'll send you *free* literature containing features, application information, ratings and specifications. George Sahl, Gates Energy Products, Inc., 1050 S. Broadway, Denver, CO 80217.

Gates®
Energy Products

Where the energy future is now

For more information, Circle No. 3

“A microp based c from for $

Most people don’t believe we sell a microprocessor-based controller for just $476.

But that’s all our Microprocessor Series (MPS) controller costs. Making it ideal for replacing hardwired and relay logic in all kinds of applications.

The key feature of the MPS controller is that it’s fully programmable. Any time you want to change a control function, you just re-program. Not re-design and re-build.

And you can use the same MPS hardware for a variety of applications. So your hardware inventory is simplified.

In addition, the MPS saves space, gives you higher reliability, and lowers system cost.

And if relay logic is what you’re replacing, you’ll also save a big chunk of money on your electric bill.

Pick up the phone and find out all the facts.

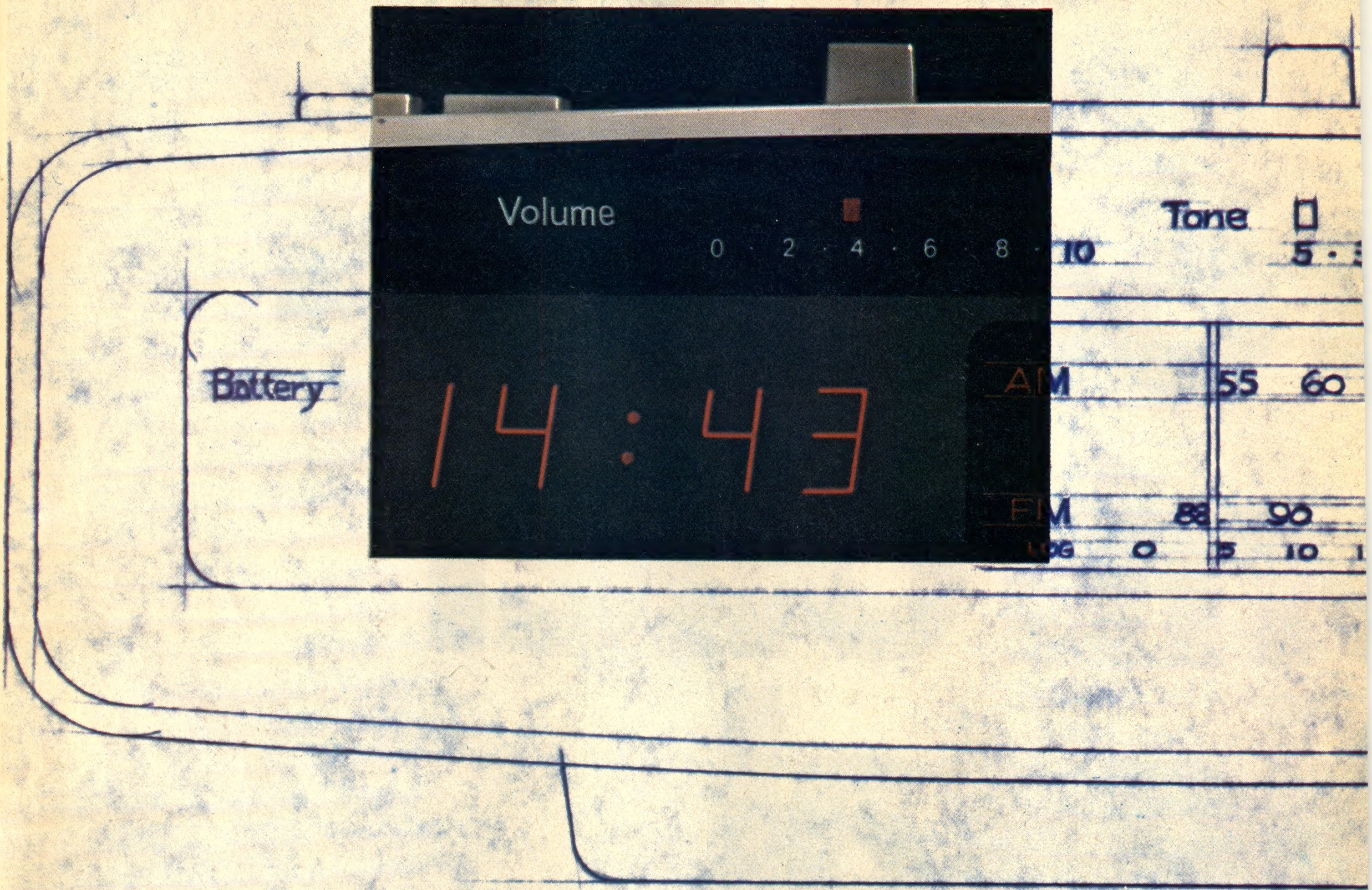
rocessor-
ontroller
igital
76?"

For $476, you just can't lose. ($476 — 100-unit price — buys the CPU with 1K of RAM. The CPU is an 8-bit parallel processor that can directly address up to 16K words of memory. Optional modules and control panel are also available.)

Components Group, Digital Equipment Corp., One Iron Way, Marlborough, Mass. 01752. Tel. 1-800-225-9480 (Mass. 617-481-7400, ext. 6653). Digital Equipment of Canada, Ltd., Box 11500, Ottawa, Ont. K2H8K8, 613-592-5111. Europe: 81 Route de l'Aire, 1211 Geneva 26, tel. 42 79 50.

digital
COMPONENTS GROUP

For more information, Circle No. 4



Better looking Beckman Displays are a natural for clocks and clock-radios

There are several big reasons why Beckman Displays are being used in more and more electronic clocks and clock radios. First, there are special 12 and 24-hour clock modules which help make application and production assembly easier. Secondly, the better looking Beckman Displays help attract buyers, help build sales. Next, in addition to multiplex mode, the displays can be DC driven to reduce RFI to a minimum.

For electronic clocks and clock radios you can choose from a variety of ½" clock display combinations from Beckman: hour and minute readouts; hour, minute, second displays; even with AM and PM indicators. Beckman Displays produce crisp, clear, unbroken numerals that add "buy appeal" to any product. They have a pleasing neon orange color (filterable to red) and are bright enough (210 foot lamberts) to be read in all ambient light conditions including direct sunlight.

Add to this the low cost (as low as $.70 per digit in large OEM quantities), the proven reliability, and you have the ideal display for today's new designs. See for yourself. Compare Beckman Displays side-by-side with LEDs or any other readout. You'll choose Beckman because they look better, are better.

For the telephone number of your Beckman/Helipot sales office, or the name of your Beckman stocking distributor, call toll free (800) 437-4677. Or write, Beckman Instruments Inc., Information Displays Operations, P. O. Box 3579, Scottsdale, Arizona 85257.

Beckman®

INFORMATION DISPLAYS OPERATIONS

For more information, Circle No. 5

There's more eye appeal in Beckman Displays!

EDITORIAL

Where have all the bold ones gone?

The more I travel about and listen to the gloom and doom talk at company after company; the more trade papers I read telling of massive layoffs; the more press releases I read about cutbacks in production and promotion—the more I wonder about what's happened to the electronics industry.

No one can ignore the fact that the current state of the economy is not one conducive to booming business. However, I can't help but remember the past 10-15 years. Except for the 1969-71 collapse of the aerospace industry, and its attendant effect on electronics business, our industry has been characterized by bold, full-speed-ahead thinking.

Look back at the number of successful electronics firms started during these years. Their success was hinged upon good planning and iron wills. If one market dried up, a new one was aggressively sought out and developed.

Now that evil times have fallen upon us, what's happened to these iron wills? It looks to me as if they have turned to "silly putty." Is this a syndrome of a small company becoming a large one? Or is it that we have been too spoiled by good business times and have forgotten how to be bold and aggressive. I see a dearth of promotion crossing my desk and wonder how our electronics companies expect to generate new business—penetrate "new electronics" markets—by becoming invisible.

Check back a year or so ago, for example, to some of the trade magazines like EDN, or check the promotional material coming directly to you, and you can see what I mean. See who was promoting their companies and their products then, and see how many of them have disappeared from sight now. They're not out of business, but you'd think they are by their meekness and low profile.

I certainly hope that our industry isn't waiting for "big brother" to declare business healthy again via proclamation. I'd like to see that silly putty turned to iron will and bold action instead.

Roy W. Forsberg

Editor

Another technical knockout

the first stable, plug-in, VHF/UHF modules

Stability — staying power under extreme conditions. Temperature. Drive. Voltage. Source and load mismatch. Now Motorola announces the broadest line of stable, rugged RF modules for plug-in between 146 to 174 and 400 to 512 MHz.

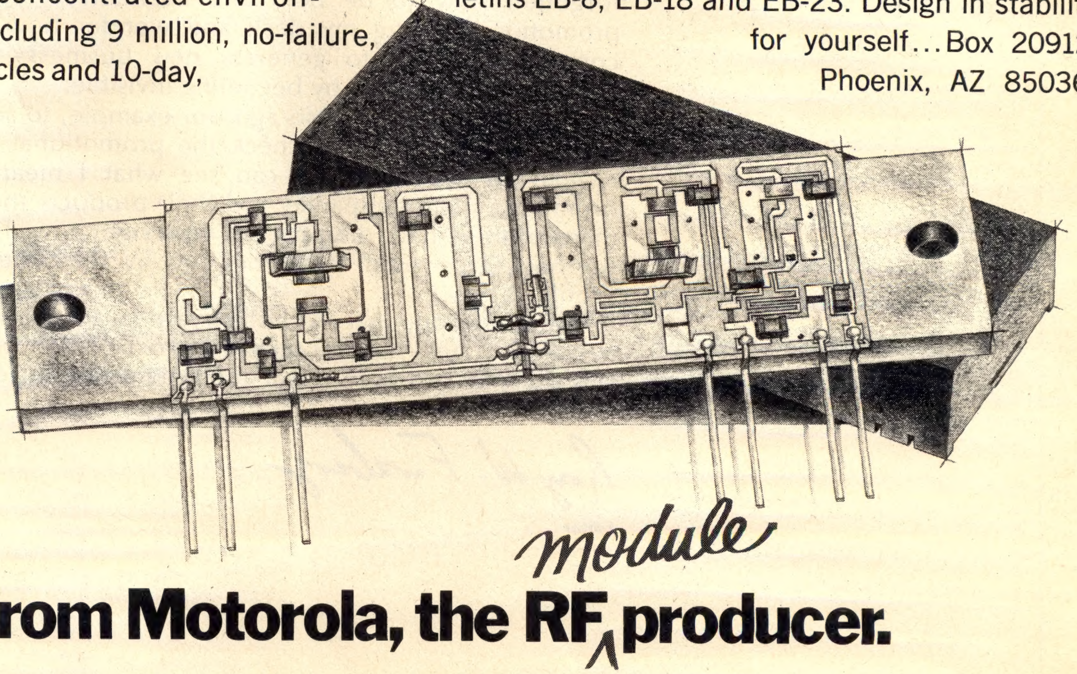
All the technology that's made us first in discrete RF makes us first in modules: Computer-designed geometry for maximized efficiency, gain and repeatability...MOS caps...deposited thin film resistors for improved reliability over Nichrome chip resistors..."CQ" devices for enhanced bandwidth and input impedance.

And they're complete. They reduce design and production to a new level of ease. **One** purchase, **one** inspection, **one** qualification, **one** piece part, **one** inventory, **one** plug-in. No field tuning. Reduced service inventory.

Two years of concentrated environmental testing including 9 million, no-failure, ON-OFF device-cycles and 10-day, 30-day and 5,000-hour MIL/DIN humidity tests indicate reliability. An extra measure of conservative rating ensures it.

Module	f_{MHz}	P_{out}	G_P dB Min	V_{DC} Supply
MHW601	146-174	13.0	21.0	12.5
MHW602	146-174	20.0	20.6	12.5
MHW401-1	400-440	1.5	15.0	7.5
MHW401-2	440-470	1.5	15.0	7.5
MHW709-1	400-440	7.5	18.8	12.5
MHW709-2	440-470	7.5	18.8	12.5
MHW709-3	470-512	7.5	18.8	12.5
MHW710-1	400-440	13.0	19.4	12.5
MHW710-2	440-470	13.0	19.4	12.5
MHW710-3	470-512	13.0	19.4	12.5

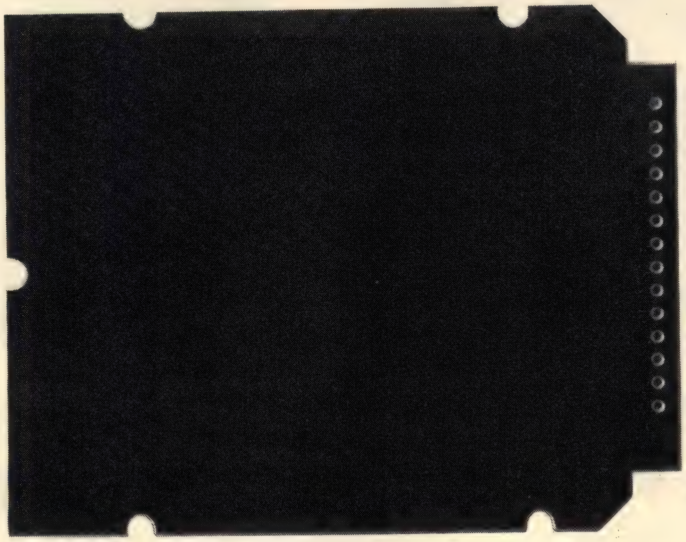
Send for data sheets and Engineering Bulletins EB-8, EB-18 and EB-23. Design in stability for yourself...Box 20912,
Phoenix, AZ 85036.



from Motorola, the RF module producer.

For more information, Circle No. 6

The only way to know which keyboard is best for your product is to feel our backside.



Gentlemen:

Feeling's believing. Show me a Bowmar Keyboard with the exclusive flat back, one-sided construction and wave solder capability. I want to see how thin this keyboard really is. All your words about Bowmar reliability won't convince me until I take a hard look at your design. So have your representative bring a sample keyboard to my office.

Name
Title
Company
Type of Application
City State Zip

Bowmar Instrument Corporation • Commercial Products Department
8000 Bluffton Road • Fort Wayne, Indiana • 747-3121

Bowmar

For more information, Circle No. 7

This NEW instrument

replaces most of what you now use to inspect R, L, and C components

It's the GR 1685 Digital Impedance Meter, which is in reality a complete incoming-inspection station for passive components. On each range it automatically measures series capacitance and inductance at either 120 Hz or 1 kHz and *measures resistance at dc.* A built-in digital limit comparator (optional) enables rapid GO/NO-GO sorting. The basic accuracy is 0.1% for dc and 1-kHz measurements and 0.5% for 120-Hz measurements. Measurement ranges are .01 pF to 20,000 µF for capacitance, .01 µH to 2000 H for inductance, and 0.1 ohms to 20 Megohms for resistance.

Other benefits include:

- **For ac measurements, D and Q limits automatically indicated (adjust dial to determine values).**
- **Measurement speed up to four measurements per second.**
- **Lighted arrows indicate direction to turn range and D/Q limit dials.**
- **Parallel data output available for external equipment such as additional limit comparators, handlers, data printers, and card punches.**
- **Test fixture (optional) has PASS/FAIL lights.**

The 1685 is equally convenient to use whether you screen many of the same type of components or measure the values of several different components. For complete information circle the number that appears below or call or write any GR Sales Office. You'll be surprised at the price, too.

General Radio

300 BAKER AVENUE, CONCORD, MASSACHUSETTS 01742

NEW YORK (N.Y.) 212 964-2722, (N.J.) 201 791-8990 • BOSTON 617 646-0550 • DAYTON 513 294-1500
CHICAGO 312 992-0800 • WASHINGTON, D. C. 301 948-7071 • ATLANTA 404 394-5380
DALLAS 214 234-3357 • LOS ANGELES 714 540-9830 • SAN FRANCISCO 415 948-8233
TORONTO 416 252-3395 • ZURICH (01) 55 24 20

GR COMPANIES • Grason-Stadler • Time/Data

For more information, Circle No. 8

STAFF

Executive Vice President and Publisher
H. Victor Drumm

Editorial Staff
Roy Forsberg, *Editor*
Walt Patstone, *Managing Editor*
Bob Cushman, *Special Features Editor*
Earle Dilatush, *Senior Editor*
Robert Drew, *Associate Editor*
Robert M. Grossman, *Associate Editor*
Tom Ormond, *Associate Editor*
Christine Loftus, *Copy Editor*

Art Staff
Dan Kicilinski, *Director*
Peter Newcombe, *Illustrator*
E. John Croswell, *Illustrator*
Ralph Stello, Jr. *Illustrator*

Production Staff
Wayne Hulitzky, *Director*
William Tomaselli, *Manager*
Meredith Tilp, *Assistant*

Circulation
Thelma Drinkwine, *Manager*

Marketing Services
Ira Siegel, *Director*

Editorial Director
Frank Egan

Editorial Consultant
John Peter

Editorial Office Addresses
Executive (617) 536-7780
221 Columbus Ave.
Boston, MA 02116

New York (212) 949 4400
205 E. 42nd St.
New York, NY 10017

West Coast (213) 933-9525
5670 Wilshire Blvd.
Los Angeles, CA 90036

Reprints of EDN articles are available on a custom printing basis, at reasonable prices in quantities of 500 or more. For an exact quote, contact Art Lehmann, Cahners Reprint Service, 5 So. Wabash, Chicago, Il. 60603 (312) 372-6880.

FLAT INTERCONNECTS YOUR COMPLETE SOURCE

Ribbon Cable / IC Interconnects / Custom Harnesses

You're sold on flat cable, now buy it at its best. Precise, compact cable packages to fit your specifications perfectly, computer-loomed for unmatched versatility by Woven Electronics.

Handling ease of independent non-bonded leads speeds production, cuts cost, while technical characteristics outrank other flat cable forms.

Make Woven your source for jumpers, continuous rolls, special harnesses, all your interconnect needs.

WOVEN ELECTRONICS
P.O. Box 189 Mauldin, South Carolina 29622
803/963-5131

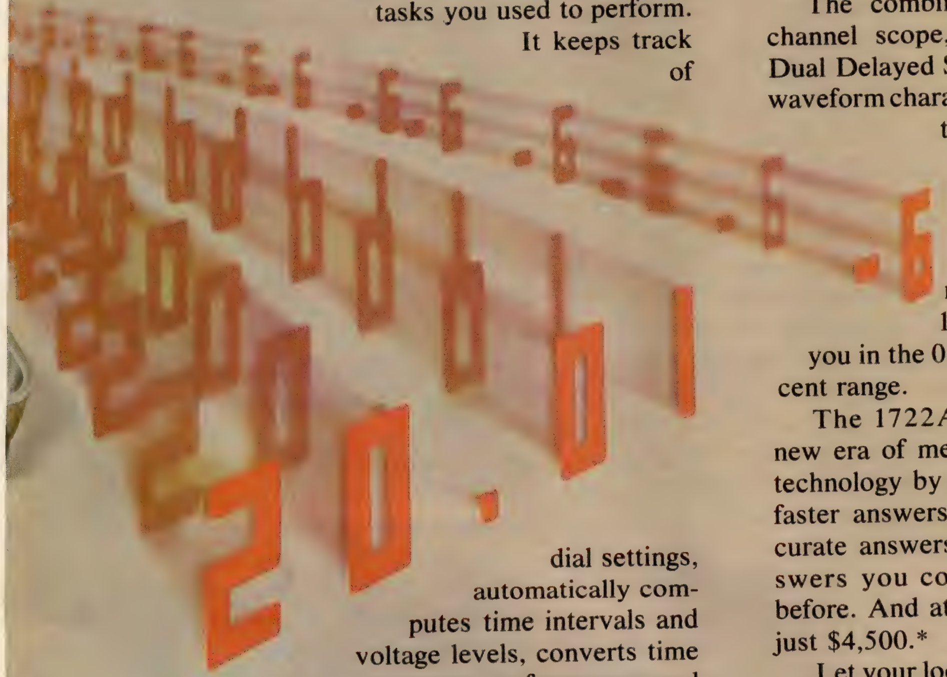
For more information, Circle No. 9

Meet the first scope with a microprocessor.

It counts, calculates, and improves accuracy too.

Now, HP has combined a high-performance scope, a microprocessor, and an LED display to put an end to graticule counting, mental calculations, and the conventional 5% scope error. The 1722A gives you a giant leap in measurement accuracy and convenience. It's a working lab partner that speeds measurements of time intervals, frequency, instantaneous or dc voltage levels, and relative amplitude. It allows you to make all these measurements more accurately . . . with less chance of human error.

The microprocessor takes over several tasks you used to perform. It keeps track of dial settings, automatically computes time intervals and voltage levels, converts time measurements to frequency, and calculates percent. It even signals if you make an erroneous setting. In addition, the microprocessor drives a 3½-digit LED display to give you a direct digital reading of your measurements . . . in seconds, hertz, volts, or percent. Working with the 1722A is like having an assistant that takes care of the mental gymnastics.



There's another reason for easier, more accurate measurements – HP's unique Dual Delayed Sweep. It gives you two adjustable intensified markers for displaying the start and stop points of a time interval. The microprocessor then gives you an automatic readout of the time interval between the markers. This speeds digital timing measurements and simplifies the adjustment of circuits to meet a timing spec.

The combination of a proven 275 MHz dual-channel scope, microprocessor, LED display, and Dual Delayed Sweep gives you faster, more complete waveform characterization than you'll get from conventional scopes costing twice as much.

And instead of the conventional 3 to 5 percent reading errors typically associated with voltage and time measurement's, the 1722A puts you in the 0.5 to 1 percent range.

The 1722A begins a new era of measurement technology by giving you faster answers, more accurate answers, even answers you couldn't get before. And at a price of just $4,500.*

Let your local HP field engineer introduce you to the new scope generation. Call him today. Or, write for our informative 8-page brochure.

*Domestic USA price only.

084/12

For more information, Circle No. 10

HEWLETT *hp* PACKARD

Sales and service from 172 offices in 65 countries.
1501 Page Mill Road, Palo Alto, California 94304

Now you see through it—now you don't

Development of a laboratory prototype of a unique aircraft window segment has been completed by Sandia Laboratories under a U.S. Air Force contract. Designed to protect a cockpit crew from the thermal burns and flashblindness caused by nuclear blast, the window uses the electronic properties of PLZT ceramic. It can be switched electronically from transparent to opaque within 50 μsec.

The prototype window measures 6×8 inches and is composed of four PLZT pieces. PLZT is a transparent lanthanum-modified lead zirconate titanate ceramic whose optical properties can be controlled by application of a voltage to a thin plate of the material.

PLZT ceramic is used in this prototype of an aircraft window segment designed to protect cockpit crews from burns and flashblindness. It is held by one of its developers, Dr. J. Thomas Cutchen of Sandia Labs Active Ceramic Materials Division. Segment can switch from 20% light transmission to <0.01% transmission in 50 μsec.

Inducing birefringence

In the window segment, a 15-mil-thick wafer of PLZT is sandwiched between crossed polarizers. This arrangement allows virtually no light to pass through the segment until a voltage is applied to metallic inter-leaved electrodes on the ceramic's surface. The chromium-gold electrode lines are three mils wide and are separated by 60-mil gaps.

A voltage applied to the electrodes alters the atomic dipole alignment of microscopic areas in the ceramic, causing it to become birefringent. Since birefringent PLZT acts as a retarder of half-wave plate, linearly polarized light entering the ceramic will exit in a voltage-dependent state of elliptical polarization. As a consequence, a controlled amount of light passes through the second crossed polarizer.

When the voltage across the electrodes is removed, the ceramic returns to its normal unswitched state within a few microseconds, and no longer exhibits birefringence. Light passage is again prevented by the crossed polarizers.

Light transmission through the window is about 20% in the "on" state. By comparison, transmission through U.S. Air Force regulation sunglasses is about 15%. Transmission through the window in the "off" state is less than 0.01%.

Quicker than a flash

A flash hazard is detected by an array of photodiodes, which in turn activates a silicon-controlled rectifier. The SCR discharges the window segment, switching it to the "off" state before the incoming light reaches sufficient intensity to burn skin or damage eyes.

The power supply, not yet fully miniaturized, displaces approximately two cubic inches and weighs about two ounces, exclusive of the battery. The unit draws about 1 mA in the "on" state, permitting about 200 hours of operation from the 5.4V battery.

Dr. J. Thomas Cutchen and James O. Harris, Jr. of Sandia's Active Ceramic Materials Division developed the window segment. They are also working on flashblindness goggles for both the Air Force and Army. The goggles, which have the same operating characteristics as the window segment, use four pieces of PLZT, two lens pieces and two side members.—*WP*

Latest study projects electronic sales to more than double by 1980

An exhaustive, in-depth packaging study projects electronic sales will reach $171.9 billion by 1980 (**Fig. 1**). This conclusion was reached by Darling and Alsobrook, a management consulting firm in Los Angeles. Four volumes, containing over 1600 pages, list the results of this research.

The volumes are broken up into the following major groupings: connectors and terminals, backplanes and sockets, printed circuits, and integrated circuits. **Table 1** illustrates the type of detailed information contained in each volume.

Darling and Alsobrook sell the study for $5000 for any one volume; $9000, $12,000 and $14,000 for two, three, and four volumes, respectively—*EV*

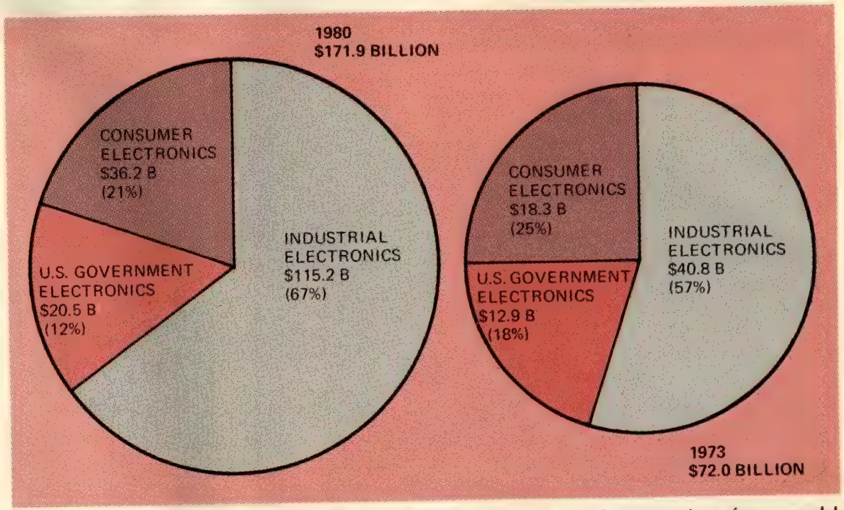


Fig. 1—Industrial electronics will get a bigger share of the growing free world electronics pie, according to Darling and Alsobrook's International Electronic Packaging studies.

Table 1—Most connector markets should grow significantly during the next five years, predicts Darling and Alsobrook.

WORLD CONNECTOR MARKET BY TYPE
COMBINED APPLICATIONS
(MILLIONS OF DOLLARS)

	1973	1974	1975	1976	1980	1973/80 GROWTH RATE
CYLINDRICAL	206	245	272	299	412	10.4%
RECTANGULAR	252	313	357	413	675	15.1
COAXIAL	87	100	104	108	118	4.5
HERMETIC	13	12	13	12	10	(–3.7)
PRINTED CIRCUIT	339	427	498	576	956	16.0
OTHER	200	258	307	359	608	17.2
FLAT CABLE	8	12	19	27	52	30.6
TELEPHONE	77	94	106	113	157	10.7
MISCELLANEOUS	115	152	182	219	399	19.4
TOTAL CONNECTORS	1097	1355	1551	1767	2779	14.2%

Advanced system developed for toll-collection operations

The new DELTA (Daily Electronic Lane Toll Audit) system went on line over the 17-interchange 241-mile Ohio Turnpike at midnight, Nov. 9, 1974. Developed by Electron, Inc. of Cleveland, OH, the system promises to give management much closer control than that possible with other systems. The most promising feature of the new system is its speed.

Audits, which have taken as long as four weeks to complete, can be accomplished within 12 hours with the DELTA system. This is of critical importance to toll collection managements in establishing accurate cash positions, and to patrons who need audit data for tax reporting purposes. The system (**Fig. 1**) reduces many time-consuming and error-prone operations to instant computer verifications.

Flexibility designed in

Each of the turnpike's lanes is linked to its plaza computers. These, in turn, are linked by telephone lines to a host computer at the Commission headquarters in Berea, OH.

Lane terminals, (**Fig. 2**), feature alphanumeric displays to convey information and instructions to the toll booth attendant. They also include a badge reader, printer, data keyboards and a mechanism to encode and decode audit information from the magnetic-stripe ticket. Since

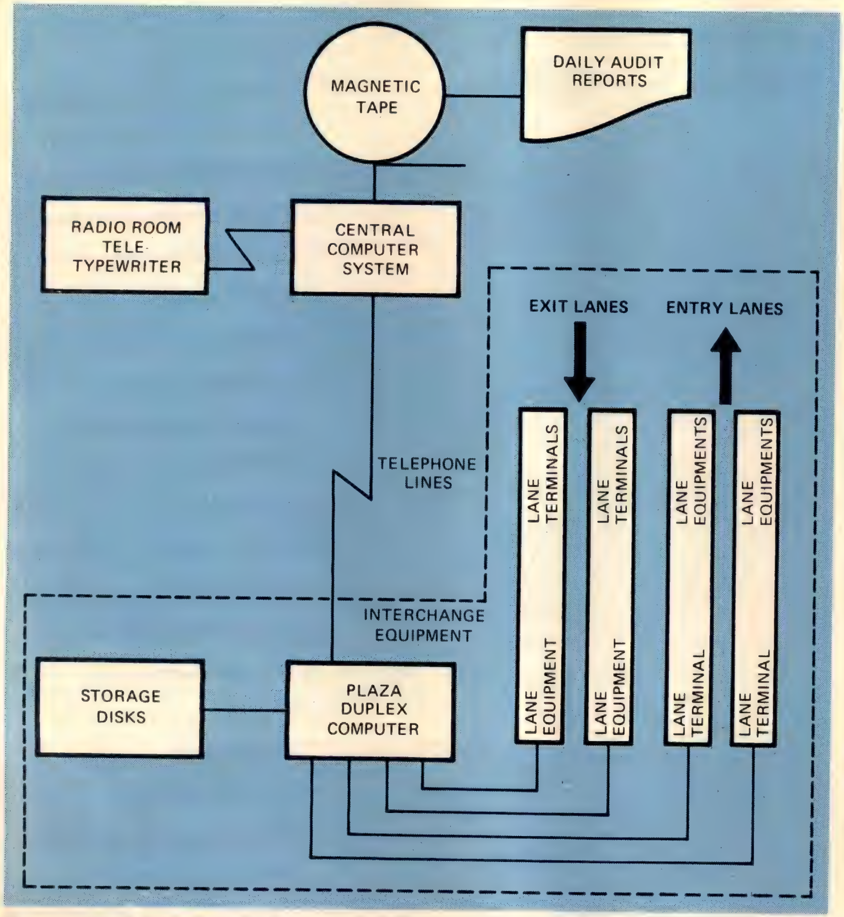


Fig. 1—Flexibility of installation is reflected in block diagram of DELTA system developed by Electron, Inc. for the Ohio Turnpike Commission. Terminals can be used in either exit or entry lanes, and interchange is completely self sufficient.

both entry and exit functions are contained in the terminal, one standard unit may be used in any type lane.

Each plaza has two computers (16k mini's with magnetic disc storage) operating in a duplex mode. One generally acts as master; the other, slave. However, both have identical software so that either machine can reverse its role.

In the event of a telephone-line failure, each plaza computer has the ability to store several days transactions under worst case loading conditions.

As data is entered at the terminal, the plaza computers gather the information, preprocess it, and hold it. Polling, done on a continuous basis, then transfers this data to the host computer.

DELTA offers much more than faster audit information. Lane terminals have self-diagnosing capability, and alert headquarters of failure. In event of malfunction, plaza personnel can handle the simple unplug, plug-in replacement. Thus, shutdown of lanes due to mechanical failures virtually is eliminated.

"Stop that thief!"

The system is said to be far more "fraud proof" than any other available. Furthermore, its flexibility permits quick and easy corrective action within the system to thwart any fraudulent practices that might evolve. Changes in audit procedures are accomplished by changing software, rather than going to new equipment.

Because the DELTA system will serve well beyond its targeted rapid-audit objectives, additional services are just now coming into focus. Besides automatic fare collection for turnpikes, other similar applications accommodated by the system include barrier stations, such as bridges and tunnels, and parking facilities.

The Ohio Turnpike installation, therefore, is expected to command considerable attention from all toll-collecting agencies throughout the world.—*TO*

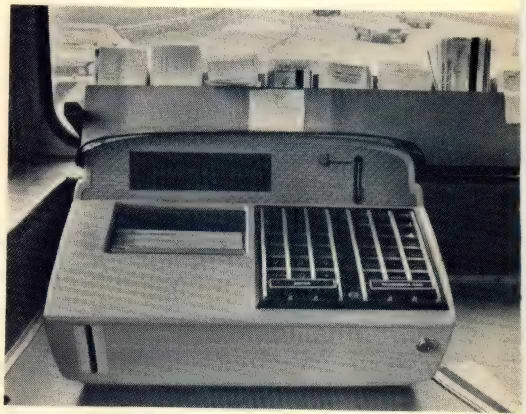


Fig. 2—Both information and instructions are conveyed to the toll booth operator by the lane terminal's alphanumeric display.

Lasers put test dummies precisely in their proper place

Lasers are helping automotive safety engineers "hold the pose" of test dummies involved in simulated crash tests at General Motors Research Laboratories, Warren, MI.

Dr. Gerald W. Nyquist and Dr. Harold J. Mertz have developed a simple and convenient method to pinpoint the initial seated position of a test subject on a crash sled. Precise location of the test sled occupant is necessary to achieve repeatable conditions and reduce variations in test results.

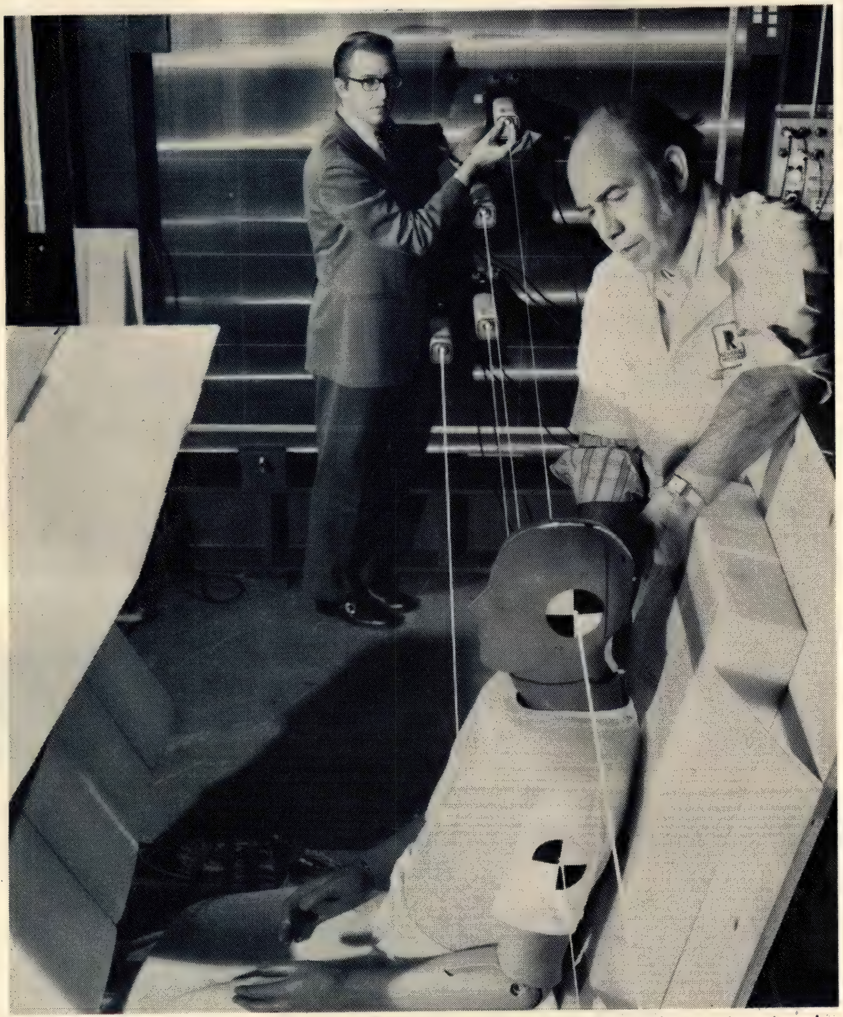
The system is part of GM biochemical studies being conducted to develop humanlike responses for automotive crash testing. Details of the process are included in a paper scheduled for publication by the Society of Photo-Optical Instrumentation Engineers.

Right on target

The GM research team uses low-power (0.7 mW) helium-neon lasers to align the test subject within an accuracy of one-tenth of an inch. The lasers are locked magnetically at predetermined positions on large vertical surface plates that are fastened to the floor on each side of the crash simulator.

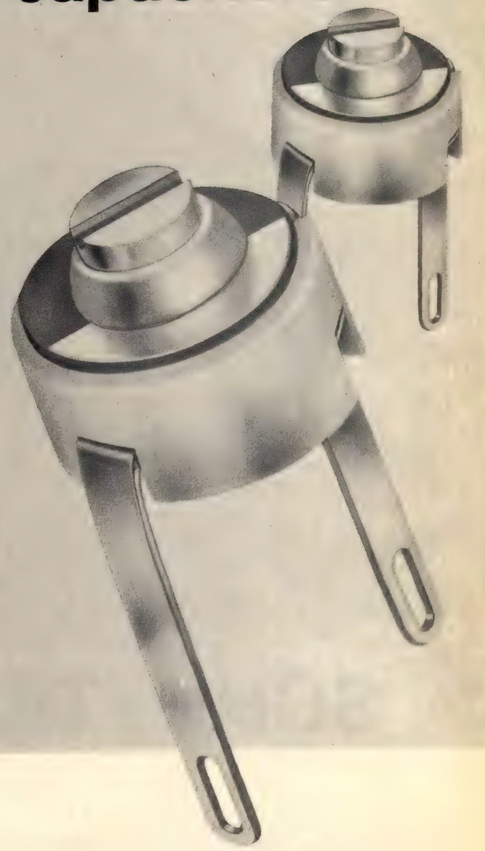
Targets on the test subject are lined up with the laser beams to put the body in the correct position for the test. As many as 10 lasers can be placed on each side of the test sled. Another laser, mounted overhead, throws a fan of light rays along the centerline of the sled to provide a lateral plane of reference.

This type of optical system is easy to use because there is no hardware to set up and move for each test, and no mechanical system that requires pointers in physical contact with the test subject—*WP*



The low-power laser beams shown in this multiple-exposure photo pinpoint the location of an anthropomorphic dummy on a test sled at General Motors Research Laboratories. This system allows repeatable conditions and reduces the variations in test results. At left is one of the system's developers, Dr. Gerald Nyquist.

low cost
ceramic
trimmer
capacitors



These ceramic trimmer capacitors are designed for broadband application, from audio to 500 MHz and afford an ideal *low cost* means of "trimming" circuitry such as crystal oscillators, CATV amplifiers and all varieties of communication and test equipment.

FEATURES

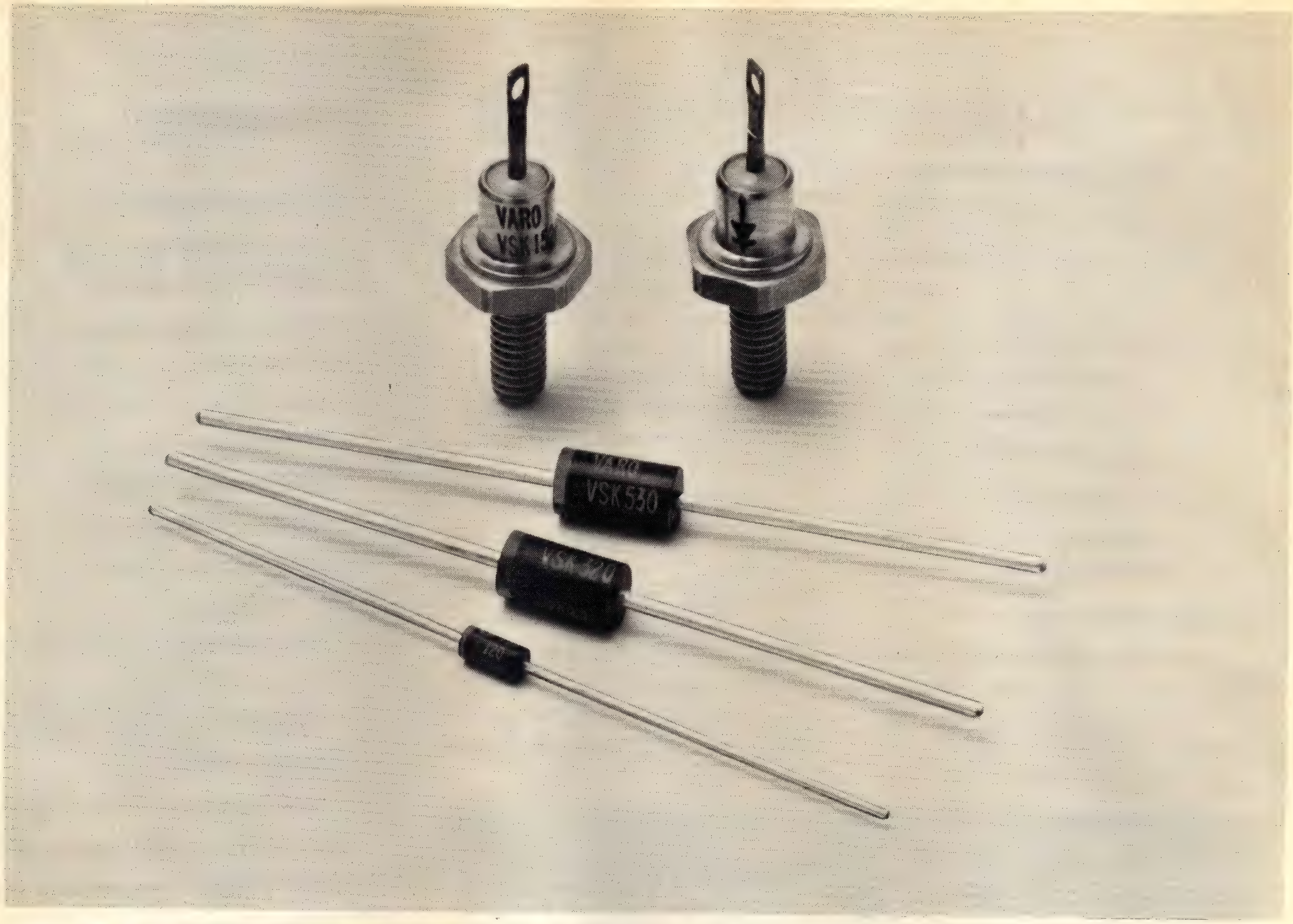
- **Capacitance values from 1 – 3 to 5 – 25 pf**
- **Low profile – .208 above board height**
- **Low cost – 75c in 1000 quantities**
- **Delivery from stock**

For more information, Circle No. 11

Johanson

MANUFACTURING CORPORATION

BOONTON, NEW JERSEY 07005
201 / 334-2676
TWX 710-987-8367



SCHOTTKY BARRIER RECTIFIERS

A new series from the advanced rectifier technology of Varo Semiconductor, Inc.

Four new series of Schottky Barrier Rectifiers are now available from Varo Semiconductor, Inc. They are rated at 1A, 3A, 5A, and 15A (I_O) with 20V and 30V (V_{RRM}).

Features are: Extremely fast recovery (t_{rr}), very low forward voltages (V_F), high reliability and low cost.

The 1A series (VSK 120 & 130) in DO-41 packages have 450 & 550 mV (V_F); 40A peak ½ cycle surge (I_{FSM}) and 10mA (I_R) at 100°C.

VSK 320 & 330, the 3A devices have 475 and 500mV (V_F); 150A peak ½ cycle surge (I_{FSM}) and 30 mA (I_R) at 100°C.

VSK 520 & 530 — 5A Schottkys have 380mV (V_F); 250A peak ½ cycle surge and 75 mA (I_R) at 100°C. Both the 3A and 5A series are in axial lead, epoxy packages.

The VSK 1520 & 1530 — 15A series are in DO-4 metal stud cases and have 550mV (V_F); 300A peak ½ cycle surge and 75mA (I_R) at 100°C.

All devices have a junction operating temperature range of −65°C to +125°C.

Typical pricing in 1000 qntys range from **$1.38** ea. (VSK 120) to **$3.67** ea. (VSK 1530).

VARO SEMICONDUCTOR, INC.
P.O. Box 676 • Garland, Tex. 75040

Please send free evaluation samples on your new Schottky type no. ____________

Name____________

Title____________

Company____________

Address____________

City____________ State________ Zip________

SEND COUPON OR WRITE ON YOUR LETTERHEAD FOR FREE SAMPLES.

Design us in . . . we'll stay there

VARO

VARO SEMICONDUCTOR, INC.

P.O. BOX 676, 1000 N. SHILOH, GARLAND, TEX. 75040 (214) 272-4551 TWX 910-860-5178

Varo Sales Representatives

AL Buchanan & Abrams Assoc. 305-898-7444 • **AZ** W. W. Posey Co. 602-949-5873 • **AR** Whiteside Sales 214-231-9771 • **CA (NO)** W. W. Posey Co. 415-948-7771 • **CA (SO)** Corcoran Assoc. 213-823-4859 • **CO** Sage Sales 801-531-0531 • **CT** Comp Rep Assoc., Inc. 203-239-9762 • **DE** Tom Davis Marketers 302-998-0123 • **FL** Buchanan & Abrams Assoc. 305-898-7444 • **GA** Buchanan & Abrams Assoc. 305-898-7444 • **IA** Coombs Assoc. 312-298-4830 • **IL (NO)** Varo Semiconductor, Inc. 312-627-3802 • **IL (SO)** Beneke & McCaul 314-434-6242 • **IN** Technical Reps, Inc. 317-849-6454 • **KS** Beneke & McCaul 816-765-2998 • **KY** Technical Reps, Inc. 317-849-6454 • **LA** Whiteside Sales Co. 214-231-9771 • **ME** Comp Rep Assoc., Inc., 617-444-2484 • **MD** Tom Davis Marketers 703-591-7390 • **MA** Comp Rep Assoc., Inc. 617-444-2484 • **MI** Davis-Martensen Co. 313-474-8300 • **MN** Loren F. Green Assoc. 612-781-1611 • **MS** Buchanan & Abrams 305-898-7444 • **MO** Beneke & McCaul, Inc. 314-567-3399 • **NB** Beneke & McCaul 816-765-2998 • **NJ (NO)** Cooper-Simon & Co. 516-487-1142 • **NJ (SO)** Tom Davis Marketers 302-998-0123 • **NM** W. W. Posey **Co.** 602-949-5873 • **NY (METRO)** Cooper-Simon & Co. 516-487-1142 • **NY (UPST)** Bob Dean, Inc., 607-272-2187 • **NC** Buchanan & Abrams Assoc. 704-332-4974 • **OH (NO)** J. C. Hofstetter Co. 216-241-4880 & 216-725-4477 • **OH (SO)** J. C. Hofstetter Co. 513-296-1010 • **OK** Whiteside Sales Co. 214-231-9771 • **OR** C. K. Shanks & Assoc. 503-292-5656 • **PA (E)** Tom Davis Marketers 302-998-0123 • **RI** Comp Rep Assoc., Inc. 617-444-2484 • **SC** Buchanan & Abrams Assoc. 704-332-4974 • **TX** Whiteside Sales Co. 214-231-9771 • **UT** Sage Sales 801-531-0531 • **VA** Tom Davis Marketers 703-591-7390 • **WA** C. K. Shanks & Assoc. 206-632-4290 • **WI** Varo Semiconductor, Inc. 414-782-7590 • **CANADA** • **ONT** Cantronics, Ltd. 416-661-2494 • **QUE** Cantronics, Inc. 514-341-5207

For more information, Circle No. 12

You already have everything you need to keep our keyboards clean.

Getting any keyboard dirty is easy.

From that point on, things become more difficult. Because the contacts on mechanical keyboards are very sensitive to contamination. And, if the dirt hasn't already gotten to them, the cleaning process might.

MICRO SWITCH makes the cleaning process easy. All it takes is a bucket of hot, sudsy water. And maybe a brush.

Because MICRO SWITCH has solid-state keyboards. Designed around Hall effect chips that are completely encapsulated, they're impervious to just about any contaminant you can name.

So things like dirt and coffee can't get in. And neither can a bath in hot, sudsy water.

It makes your equipment maintenance a lot easier. And, in the long run, can substantially reduce service costs. Besides giving you a keyboard with all the built-in reliability of a solid-state design in the process.

If you'd like more information on MICRO SWITCH keyboards, call, toll-free, 800/645-9200 (in N.Y., call 516/294-0990, collect) for the location and telephone number of your nearest MICRO SWITCH Branch Office.

You'll see a line of keyboards that work like a dream. And wash like a coffee cup.

For more information, Circle No. 13

MICRO SWITCH
FREEPORT, ILLINOIS 61032
A DIVISION OF HONEYWELL

MICRO SWITCH products are available worldwide through Honeywell International.

Introducing the incredible Nitron EAROM memories...

Won't blow their minds in a blackout.
Erase in one second... up to a million times.

Our non-volatile, electrically alterable, read-only memories (EAROMs) are the tiny memory devices that do it all:

1. They can store data for years without power.
2. They're non-destructive and immune to external power interruptions.
3. They let you erase stored information in just one second, without ultraviolet irradiation.
4. They let you alter the memory as often as needed —up to a million times.
5. They're particularly useful for communications, computer peripherals, and very low power applications.
6. Standard products and custom capability.

Part Number	Description	Power Supplies (Volts)	Package	Notes
NC7001	64 x 1	±15	18 DIP	ROM Organization
NC7002	1024 x 1 512 x 2	±15	40 DIP	ROM Organization
NC7010	1024 x 1 512 x 2	±15	28 DIP	ROM Organization
NC7030	8 x 16	±15	18 DIP	Shift Register Stack
NIT-80C	1K x 8	±15	PC Board	8K Memory Module
NIT-80T	1K x 8	±15, +5	PC Board	8K Memory Module

Before you forget, call us at (408) 255-7550.
Or send the coupon for the full NITRON story.

NITRON A division of **McDONNELL DOUGLAS**

For more information, Circle No. 43

NITRON, 10420 Bubb Road, Cupertino, CA 95014

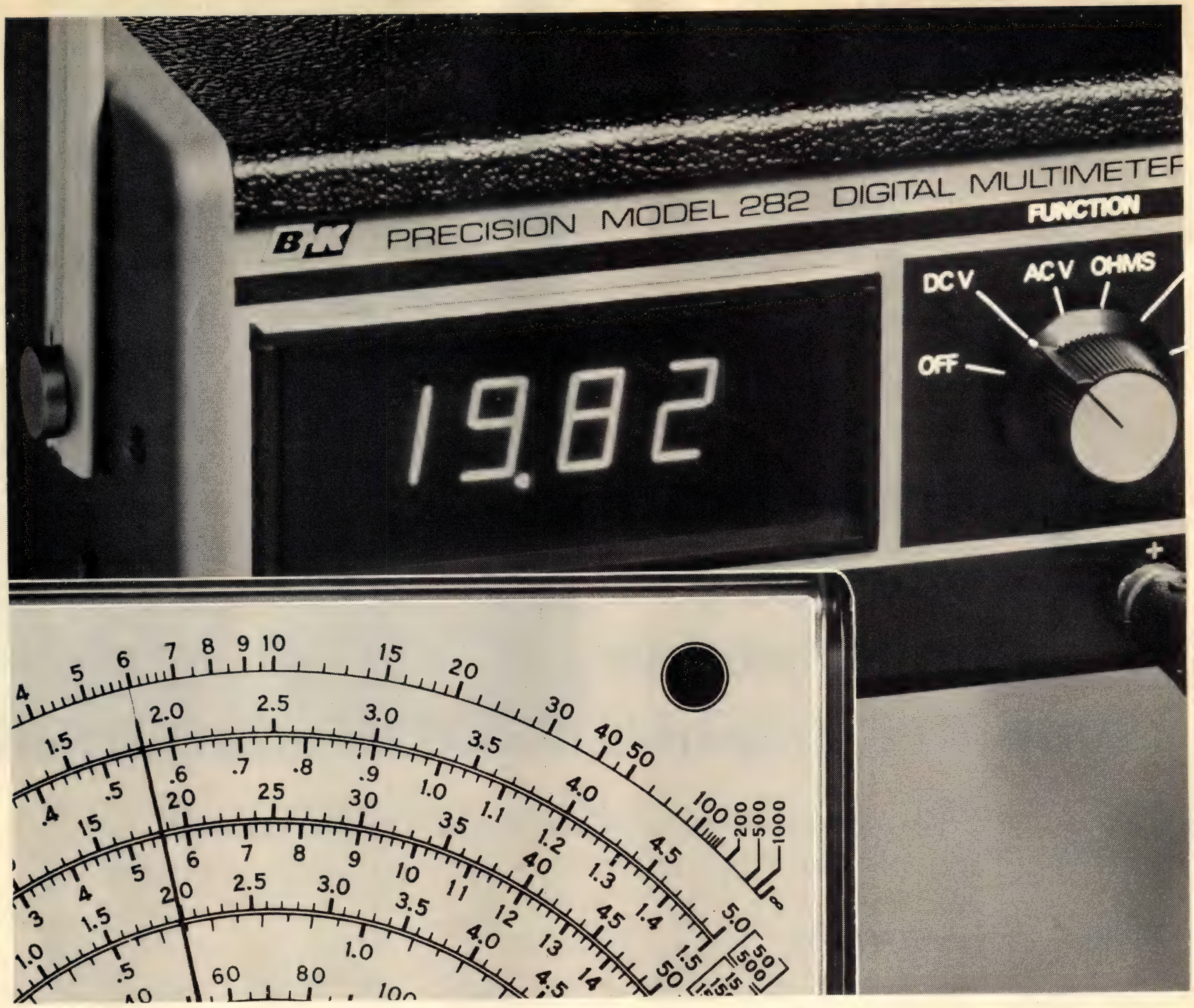
Before I forget, please tell me more about NITRON memories.

name

company

title

address



What's the Difference?

3-1/2 digit multimeter with 6 to 13 times the accuracy of a typical analog meter

The industry's most popular bench-type VOM, compared above to our Model 282 Digital Multimeter, has 3% full scale DC accuracy. On the 50-volt scale, that's an accuracy of ±1.5 volts, or an *accuracy of reading* of 7.5% at about 20 volts. The 282's accuracy of reading is 0.5% ± 1 least significant digit, or ±0.11 volt. Divide those two figures—1.5 by 0.11—and you find that the 282 has 13.6 times the accuracy at that reading.

Even at readings close to 50 volts, where the analog multimeter is most accurate, Model 282 *remains more than six times as accurate as the analog multimeter.*

As for ease of reading . . . the picture above shows Model 282 and the analog meter full size. Put it where you'd normally set up your multimeter and see for yourself how much more easily you can read the 282's bright digital display.

And there's more—automatic polarity, clear out-of-range indication, automatically positioned decimal point, 100% overrange capability, complete overload protection, 10 megohms input impedance and a three-position handle that doubles as a stand for tilt-up viewing. Plus a Model PR-21 probe with switchable 100K ohm isolation resistor to prevent capacitive loading while measuring DC in RF circuits.

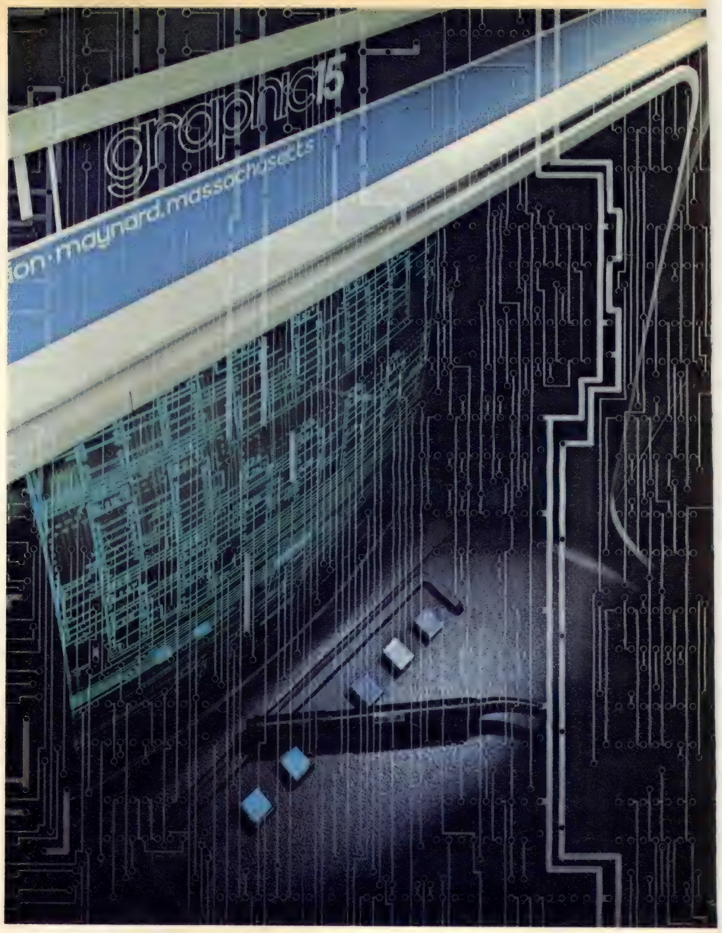
And all for almost an analog price! Now in stock at your local distributor or write Dynascan.

MODEL
282
$200

B&K PRODUCTS OF DYNASCAN
1801 W. Belle Plaine Ave. • Chicago, IL 60613 • Phone (312) 327-7270

For more information, Circle No. 14

DESIGN FEATURES



Simplify pc board design with autointeractive computer graphics

Take some CAD, a little automatic drafting, add a dash of human judgement and mix well. Then watch your time and cost hit a new low.

Eli Glazer, Digital Equipment Corp.

"Autointeractive" computer graphics is a relatively new computer-aided design technique that results in faster turnaround times and significant cost reductions over conventional methods. The term "autointeractive" represents the concept of employing designer creativity and electronic computer speed and precision to develop optimized designs in the shortest practical period of time.

As a technique, autointeraction divides the workload between designer and computer to realize the strengths of both. One area in which autointeractive computer graphics has found acceptance is in the layout and design of printed-circuit boards. It has already demonstrated significant savings—between 60-80% cost savings and 80% time savings on development schedules.

The new technique lends itself particularly well to current design, where higher part densities on circuit boards are quite common. It can also be used for design of IC masks, and layout and design of thick- and thin-film circuits.

In this corner we have batch,...

To place the benefits of autointeraction in perspective, let's review the other design alternatives available: fully automatic computerized design and computer-aided drafting.

The fully automatic technique generally is used with a large-scale computer system configured for batch processing operations. Thus, it has those problems inherent with any batch processing operation. These primarily involve turnaround time and ease of error correction. Once the designer inputs all his design elements, there is no way for him to intervene until a final design is output; the program must make all design decisions.

Use of a batch-processing computer system is a fairly expensive proposition, both with regard to equipment costs and man-hours of preparation. But the lack of flexibility in such a system is the most important consideration. During design development, changes are likely to occur between the advent of the initial concept and the final, approved design. Effectively, most design and layout problems are developed iteratively. With a fully automatic design system, each iteration occurs only at the end of each batch run.

Over here is automated drafting...

The other "traditional" approach is computer-

Development of appropriate hardware and software for medium-scale computers makes autointeractive graphics economically desirable. Digital's Graphic 15 system uses both high- and low-speed mass storage devices.

aided drafting. Here, the designer interacts with the computer system to develop his design. Typical computer-aided drafting systems employ a storage-tube CRT. The designer manipulates a cursor to pinpoint circuit element connection points, and thus interacts with the computer system in developing his design. Usually, entry for new data or instructions is made via the terminal keyboard, allowing the designer full contact with the computer system. He has an immediate display of his design, and can bring his full experience to bear on the problem of parts placement, path routing and so forth.

However, such an approach is not much better than an automated pen and eraser. Whether the layout is done through the physical process of drafting or the use of tapes and pads, the designer has to perform all actual layout functions. In a sense, therefore, such computer-aided drafting is essentially a manual operation, though it does conserve drafting materials such as vellum. And as a consequence, little time is saved in layout over conventional drafting. The principal benefit is mechanization of the actual drawing process with the attendant generation of numerical control tapes to drive the precision artwork plotter.

And the winner is?

Well, there really isn't a winner. As can be seen, the two conventional methods tend to complement each other. The fully automatic approach is rapid and performs detail work, but it does not permit the designer to control the process during a run. The computer-aided drafting approach permits designer interaction, but is slow; it requires the designer to concern himself with each element of the total design without any assistance from the computer.

Autointeractive graphics combine the strengths of both traditional techniques (**Fig. 1**). Using a refresh CRT and a light pen, the designer forms an immediate feedback loop to the system while the design is still in process. Yet he can call upon the computer's software packages to fill in certain areas of detail, such as exact coordinate location of parts used in the layout.

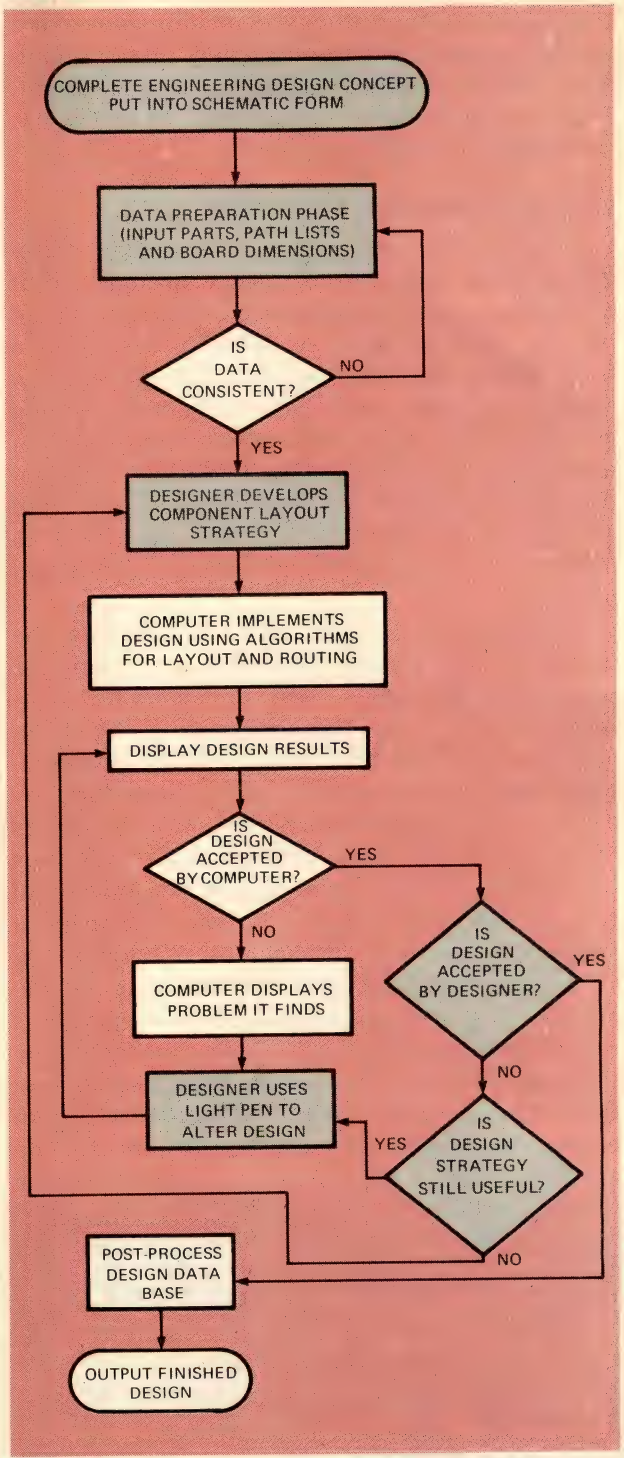

COMPLETE ENGINEERING DESIGN CONCEPT PUT INTO SCHEMATIC FORM
DATA PREPARATION PHASE (INPUT PARTS, PATH LISTS AND BOARD DIMENSIONS)
IS DATA CONSISTENT?
NO
YES
DESIGNER DEVELOPS COMPONENT LAYOUT STRATEGY
COMPUTER IMPLEMENTS DESIGN USING ALGORITHMS FOR LAYOUT AND ROUTING
DISPLAY DESIGN RESULTS
IS DESIGN ACCEPTED BY COMPUTER?
YES
NO
IS DESIGN ACCEPTED BY DESIGNER?
YES
COMPUTER DISPLAYS PROBLEM IT FINDS
NO
DESIGNER USES LIGHT PEN TO ALTER DESIGN
YES
IS DESIGN STRATEGY STILL USEFUL?
POST-PROCESS DESIGN DATA BASE
NO
OUTPUT FINISHED DESIGN

Fig. 1—Flowchart shows design process of autointeractive graphics. Gray blocks indicate operator control while clear boxes signify computer control.

The automatic element of the process may only develop 95% of a finished layout. The designer completes the design and transforms it into one that is practical to manufacture, has a higher production yield, is more serviceable and, yes, is even more aesthetically pleasing. The automatic part of the process relieves the designer of time-consuming, laborious steps in a layout. This encourages him to re-try the whole process if another strategy might prove to be a better solution.

Through autointeractive graphics, the designer directs the system in automatically routing a given circuit. He can then study the relationships of the various components from the very first "preliminary" design executed by the computer system. Thus, as well as being a design aid, the terminal is inherently a visualization tool.

If at first you don't succeed...

The designer can explore many design strategies quickly and without delay. Through use of his light pen, a component pad or connection can be relocated. If the new location results in a better design, he tells the system to use the new location as part of a more effective routing arrangement, which the autointeractive system executes automatically. The designer's optimization of his component placement can take into account factors that would be impractical to include in a fully automatic design and layout program.

By interaction through use of his light pen, the designer can reduce board space, eliminate plated-through holes, add or eliminate components, and trace complex routings. And because of the real-time nature of the presentations, the designer can see, or be alerted to, any errors he is making almost as soon as he makes them. Time lag for correcting errors is thus minimized. Rather than having to paste and repaste lines and pads, or tolerate a poor initial strategy, a light pen can make these corrections.

Perhaps the best way to demonstrate the autointeractive computer graphics design process would be by means of an example. The technique to be described is one used by Digital Equipment Corp. They employ the PDP-15 graphical system with software written by REDAC Software Ltd. The example chosen is that of a relatively simple printed-circuit board having components on only one side and "wiring" on both sides—the type of pc board commonly found in consumer, industrial, commercial and military electronics (**Fig. 2**).

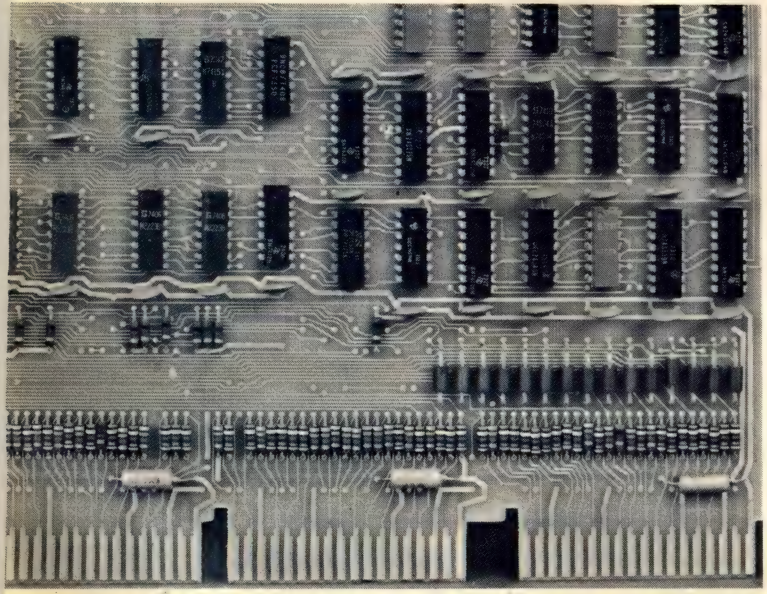


Fig. 2—Doubled-sided pc board shows autointeractively generated patterns. The regular, straight-line paths produce a "mechanical" effect typical of computer optimized programs.

A list is a list, is a list.

First step in the design is to prepare a series of lists that will be entered into the system via punched paper tape. These include a library list, component list, wire list and board list.

This phase of operation resembles a fully automatic computerized layout and design procedure. The library list defines pad positions and sizes for each component, plus the pin locations and connectors involved. The component list names each component to be used in the (initial) design and layout. Component shape is drawn from the library list. Also, the component list specifies the orientation of each component and identifies which side its pads will be located upon (and, optionally, the position of pad No. 1). The wire list indicates which circuit points are connected among themselves, without any specific routing information. The board list specifies the X and Y coordinates of corners of the board upon which the circuit will be laid out. Size of these lists is determined by the program (**Table 1**).

TABLE 1

CAPABILITIES OF AUTOINTERACTIVE SYSTEM

Maximum Number of Components	450
Maximum Number of Connections (Note: 1750 with addition of 16K or core)	1000
Maximum Number of Pads Per Component	63
Maximum Board Size Using 0.025-in Grid	25 x 25 in.
Maximum Component Size Using 0.025-in Grid	12.7 x 12.7 in.
Maximum Number of Connections to a Component	255
Maximum Number of Pad Types	40
Maximum Number of Line Widths	7
Maximum Number of Board Corners	23
Maximum Number of Segments* in a Route	30

*A segment is any single straight-line part of a route.

Because of its equivalency to the fully automatic process at this stage, particular care must be taken in preparing these lists. The wire list contains the largest amount of data, and is most likely to contain errors. For this reason, two people prepare wire lists independently.

Once all lists have been compiled, they are fed into the computer system for validation by a REDAL™ routine (**Table 2**). In the case of the wire list, two separately prepared wire-list tapes are entered and compared. Any anomalies to the entries are noted so that the designer can make necessary changes.

A CRT is quicker than the eye

Once the input data is validated, the designer has the outline of the board displayed on the screen of the interactive terminal. Another REDAL package performs a preliminary design layout, displaying both component shapes and interconnections from information supplied. Presentation of the design is quite rapid, though actual times involved vary with the number and type of components and their interconnections. Typically, preliminary layout is achieved in seconds after validation (**Fig. 3**).

It is possible, particularly with designs of units that have very low part densities, that the preliminary design will be completely acceptable. In such a case, the designer would merely review it and determine if the design could be classified as the final layout. Such cases would be less likely as the complexity of the design increases.

TABLE 2

AUTOINTERACTIVE COMPUTER GRAPHICS SOFTWARE ROUTINES

GRID–	A routine that places all components on a regular grid. The international standard 0.1000-inch grid is used, unless the designer defines another grid. This routine makes the final alignment of a component that the designer has moved by shifting it from whatever position he moved it to the nearest exact grid location, saving the designer time he otherwise might have to spend in precise alignment.
CENTER OF GRAVITY–	A routine to move components while maintaining continuity of their connection paths to minimize their lengths.
SWOP–	A routine to interchange pairs of components in order to minimize the length of connective paths. Components fixed in place by the designer cannot be moved by the SWOP (or center of gravity) routine.
MINICON–	Another routine to minimize connection lengths; this routine assumes that the components involved are fixed in place, in contrast to the CENTER OF GRAVITY routine.
ZROUTE–	An automatic routing routine to establish actual printed wiring patterns.
MOVE–	Routine to permit components to be moved, rotated, or fixed in the design, via light-pen interaction. Continuity of connective paths is maintained throughout the move.
MODIFY–	Permits the operator to add a component (if in the system's component library) or a connection, or to delete a component or connection, in an on-line mode.
WINDOW–	Routine to permit the designer to work with a subsection of the whole design. The "window" established can be moved across the design; detail within the window can be expanded to fill the whole screen. An automatic feature of this routine is that it compensates for additional information by expansion, in case the operator has requested more than is in the original window.
MANHAT–	Checking routine to ensure that line-to-line and line-to-pad spacing is valid, and that crossovers do not occur. All invalid routes flash, to attract the attention of the designer.
BRITEUP–	Routine to isolate elements of a board in the CRT display by varying the brightness of the items of interest.

Now, let's interact

For the average pc board employed today, the design "submitted" by the computer system would require some optimization by a designer. For a highly complex layout, it might require extensive modification.

A common change that designers will make is to rearrange components. This generally is done to satisfy some requirement realized by the designer that otherwise would be beyond the scope of any practical automatic placement program. Considerations for rearrangement might be thermal, situating heat-generating components far from other components or areas that might be sensitive to elevated temperatures; mechanical, either for ease of component insertion during manufacturing or to prevent unbalanced concentrations of mass in certain spots; and maintainability, in that components most subject to replacement be easily accessible. Frequently, the designer's judgement is required to balance these three considerations.

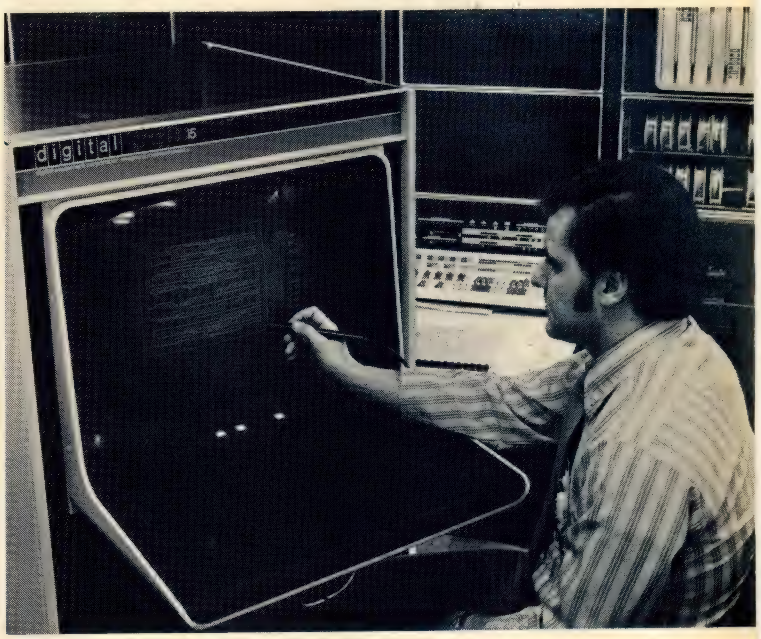


Fig. 3—A central system element is a core refresh graphics terminal with a light pen; it includes a special-purpose graphical processor to generate the display.

The light pen moves or places the components. After selecting the PLACE command with the pen, the designer chooses one of several available REDAL placement programs. He then indicates, via the light pen, how he wishes to arrange any or all of the components presented on the board, in accordance with his own design criteria.

After the designer makes his placements, the system's automatic interconnection routines define circuit "wiring" paths between components. Results still may not please him, and through manual interaction with the graphic display terminal, he can make further refinements. Such an iteration might take several cycles before the designer is satisfied. MINICON is then called to minimize the path lengths of interconnections while retaining the same connections.

Interconnection paths, which are still merely no-width pathway indications, must be converted into proper printed wiring or routes, between board components. These paths must conform to both line-to-line spacing and line width requirements, and must remain free of potential short circuits.

To do this, the designer employs the automatic routing routine, ZROUTE. With the light pen, he defines the areas available for routing. As many routes as possible will be found, and the number of plated-through holes will be minimized automatically. Through use of different intensities, the system simultaneously displays both sides of the board without causing confusion.

If certain routes cannot be completed automatically, the computer notifies the designer. He then draws the required routes, and modifies those routes already completed, if required to do so.

The computer never forgets

During the entire routing process, the computer system is continuously monitoring all routes, both for line-to-line and line-to-pad spacing. In addition, it monitors routes for possible crossovers, which would result in short circuits. If an error takes place, the sections causing the problem begin to flash, thus attracting the designer's attention. He can then correct such routing errors manually.

This process in particular serves to highlight the advantage of the autointeractive approach. Computer systems are immune from fatigue and boredom. They can continuously monitor all elements in a design, which would be difficult for a human designer to do. The designer, with his creativity and experience, can develop routings that would be beyond the capability of the computer to come up with. Where one-half of the man-machine team is weak, the other is strong, and they complement each other perfectly.

Throughout the entire design and layout procedure, the designer can use the system's "windowing" or "blow-up" feature. He can isolate a particular working area for detail work (to form a "window"), and then enlarge it to fill the screen of his graphical display. Once formed, a "window" can be moved across the total design to any spot of interest.

When the design is complete, another REDAL package produces final artwork, drawings for component placement, and numerical control tapes to run drilling machines for the finished boards. This straightforward and automatic process does not require the designer's time. Again, the computer system is employed in the area of its greatest strength—minute attention to details and operation at high speeds. The designer is free to work in his area of greatest strength—experience in circuit design that includes both familiarity with components employed and their design problems, and creativity and imagination.

You gotta believe

Digital has proven the use of autointeractive computer graphics in the design of computer boards and subassemblies with the following results: Design cost of printed circuit boards can be halved. The cost to design backpanels can be reduced by at least 60%; backpanel manufacturing costs can be cut 80% or more. Development schedules for backpanels can be reduced by at least 80% in engineering, 75% in manufacturing.

The direct result of this approach has been to produce optimized designs accurately, rapidly and inexpensively. Those who have used autointeractive graphical design systems predict an exciting future for this process. □

Acknowledgement

The author wishes to express his gratitude to REDAC Software, Ltd., of Tewksbury, England, for supplying information concerning autointergraphic software packages and their capabilities.

Author's biography

Eli Glazer is manager of the PDP-15 Design Automation Systems for Digital Equipment Corp. in Marlborough, MA. He was previously employed by Brookhaven National Laboratory and ITT. Eli, a member of IEEE, received a BSEE from CCNY, an MSEE from Columbia Univ. and his P.E. license from New York. His outside interests include sailing and tennis.

Over 50,000 people now own our 8000A. It's the best selling DMM in the world.

Read why:

The average DMM lets you down in one performance area or another. By contrast, the Fluke 8000A 3½ digit multimeter offers you the industry's broadest and best combination of outstanding specs, including some that are unmatched anywhere.

- ***Best accuracy statement*** of any 3½ digit DMM: 0.1% accuracy ± 1 digit; one year accuracy time span; 25°C ± 10°C accuracy temperature span.
- ***Outstanding normal mode rejection:*** 60 dB at 50 and 60 Hz.
- ***Outstanding common mode rejection:*** 120 dB with an unbalance resistance of one kilohm.
- ***Overload protection*** specified for *all* ranges, not just some.
- ***26 ranges*** of volts, amps and ohms.
- ***More option power*** than any other DMM. Includes 2 ohm and 20 ohm range option. 20 amp current capability. BCD output. Built-in, self-contained, rechargeable battery pack.
- ***More accessories*** than any other DMM. Includes 600 amp AC clamp-on current probe. 40 KV high voltage probe. 100 and 500 MHz rf probes. 3 types of rack mounts.
- ***Auto zero.*** Automatically sets zero reference, eliminating the need for front panel manual adjustment.
- ***One year unconditional warranty.*** Forty-eight hour local service.
- ***The incomparable Fluke reputation.*** Just ask anybody.
- ***Price still only $299.*** (domestic only)

For data out today dial our toll free hotline 800-426-0361.

For a demo circle 260. For literature only circle 261.

For info on the rest of the Fluke line see our ad in EEM or the Gold Book.

John Fluke Mfg. Co., Inc.,
P.O. Box 7428, Seattle, WA 98133.

FLUKE®

Low-cost DMM's—two sets of views on what they should be and do

By their very nature, the under-$200 DMM's offer limited accuracy, but they shouldn't stint on safety or be inconvenient to operate.

Earle Dilatush, Sr. Editor

Lately, low-cost digital multimeters have begun to challenge such old standbys as the Simpson 260 and the RCA Voltohmyst. They're doing it head on, too, for DMM prices have dropped to the point where a prospective buyer can elect to go either analog or digital.

We might ask what brought this about. One factor that has had a large effect on prices is the drop in readout cost, largely caused by electronic calculators. These calculators, with their high-volume usage, greatly hastened price erosion and provided a fallout benefit to the DMM user.

Now that low-cost DMM's are a reality, we felt it would be useful to find out just where these new work horses are headed. So we asked two people whose companies make DMM's to tell us what we should look for when shopping, and what capabilities we can expect to get.

Don't let the designers burden you with unneeded goodies

Carl Korn, B & K Precision

Measurement accuracy seems to be an obsession with some designers of DMM's. They tend to favor doing a sophisticated job, while users generally are more interested in protection against damage to the meter, and in convenience of use.

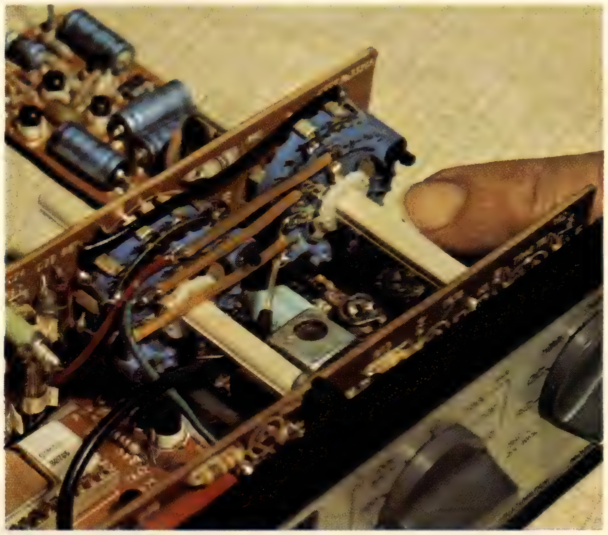
In the first five years of DMM history, everyone seemed caught up in the desire to produce 0.01% instruments. Such accuracy was possible, of course, but look at the many millions of analog measurements made daily to 1, 2, or even 5%. They make 0.01% capability look like overkill.

Some types of measurements do demand extreme accuracy, but it's foolish to think that there is magic worth in making all measurements that way.

Often only the knowledge that a voltage is present is required—and you don't need a 0.01% meter to tell that.

Today the DMM users who make measurements on the production line, in repair shops and in industry generally are less skilled than previous users. They've had less training, and are more apt to read analog indicators incorrectly. Not only that, but in many instances the job they do has broadened.

As an example, take B & K's own plant maintenance man. He must handle not only mechanical, but electrical and electronic chores as well. He's more of a generalist and less of a specialist, therefore he needs all the help he can get from easy-to-use test equipment. Digital presentation certainly makes his job easier. This applies to production and incoming test people,



Safety rated high on this DMM's design priority list—note the plastic switch shafts and knobs. (*Ballantine Labs.*)

too. They easily can make errors in reading many-scaled analog meters.

A large percentage of users need lower cost instruments with accuracies adequate for the intended use.

This equipment must be easy to use and maintain, be reliable, and be designed to protect both the instrument and the user. Undue emphasis on reading speed seems inappropriate. After all, our visual perception requires milliseconds, not microseconds.

What should a good low-cost DMM provide? A pat answer would be "what the user needs and wants." But there are a few things you should insist on:

- **A convenient physical package.** If you anticipate making most measurements at a bench, and if the instrument is ac powered, be sure it has large enough readout digits to let you work comfortably at the end of the test leads. Plastic cases provide insulation as well as durability, but check that supplementary shielding has been incorporated.
- **An easy-to-read display.** The ease of reading varies widely on low-cost DMM's. By far the best way to choose, if possible, is to use them. When you do, be sure to note what sort of out-of-range indication has been provided. On our DMM's, the display gives unmistakable warning to the user. On the 3-1/2-digit Model 282, this consists of the first digit reading "1" and the others blanking out when the input exceeds the F.S. value for a range (the instrument provides 100% overrange, so any input that would read above 1999 actuates the out-of-range display blinking).
- **Adequate functions and measurement spans.** Minimum functions for most uses should include dc and ac voltage, dc and ac current and resistance. Few users need or should be asked to pay for high-accuracy ac measurements—or high-frequency ac measuring capability. Low-cost DMM's can't yet provide true rms readings, and neither the peak-responding or average-responding types (both are calibrated to read the rms value of a true sine wave) give accurate readings unless the input is a pure sine wave.

• Autopolarity? Insist on it. It costs little to include, but offers a big bonus in making the instrument easier to operate.

- **Protection for the instrument.** We feel strongly that all DMM's, regardless of price, should be well protected against overloads. (Despite the best of intentions, every meter will surely encounter an accidental overload at some time in its working life.) For example, our Model 282 provides unconditional protection to 250V on Ω ranges, 3A on current shunts and 1500V on voltage ranges (keep your measuring probes away from the high voltage in TV sets and high RF voltages, for they can damage most DMM's).
- **Convenience features.** Look for such things as a multi-position adjustable handle/tilt stand, simple unambiguous switching, battery option (preferably with a positive indication of battery condition), just two input test leads for all measurements (we provide a probe that contains a switchable 100 kΩ resistor to prevent capacitive loading when measuring dc in RF circuits, and which can be used for all the DMM's measurements), plus provisions for fast and convenient servicing.

Where should you buy your low-cost DMM? We feel that items with price tags around the $200 mark are best purchased from electronics distributors, rather than from company salesmen or instrument sales representatives ("the 15%ers"). It's primarily a matter of economics.

A sales call now costs about $50 to $70, so for the salesman to break even there would have to be at least two $200 instruments sold on every call.

In addition, the "15%er" might be tempted to sell you a higher priced unit in order to make out.

How does this affect you? It's quite simple. A salesman obviously can't afford to give you much time or help when his margin is so slim. He has to "sell and run" to keep solvent. This is not true for the electronics distributor. Since he has a broader line, plus component lines, to sell—it's less costly for him to make sales calls. Thus he can afford to spend time with all people who influence the purchase. You are his valued customer and he wants to keep things that way. Therefore he can, and will, help you get satisfaction from what you buy.

Most important, your distributor will stock DMM's, so you get off-the-shelf delivery.□

Author's biography

Carl Korn is President of Dynascan Corp. in Chicago. He holds a BSEE from CCNY, and founded the B & K Mfg. Co. (now Dynascan Corp.) in 1954. Basically practical, Carl feels strongly that need, not technical glamour, should determine what instruments should be designed and produced. He lives in suburban Lincolnwood.

Analog MM's move over, here come the digital challengers

Fred Katzman, Ballantine Labs

Dry-cell power offers complete power-line isolation at reasonable cost. A low-voltage dc supply-on-a-plug permits safe, well isolated line operation as an alternative. (*Ballantine Labs.*)

Because they do the job better and are easier to use, low-cost DMM's now provide an attractive alternative to analog when you're in need of a multimeter. It's not hard to see why, either. They handle most of an analog multimeter's tasks, and do something no analog meter can—read out directly in highly visible digits. Analog meters still handle some measurements better, of course. No digital meter is as useful for following rapidly varying signals such as occur when nulling. Likewise, the presence of considerable noise may only result in some jitter on an analog meter, but drives a digital one crazy.

Since we're talking about replacing analog multimeters with DMM's, it may be a good idea to review the features you should look for when scanning the field.

Size ranks high on the list of points to consider. The dimensions of the Simpson 260 seem like a good compromise.

A DMM that's too small opens up the possibility of its being lost or stolen. It's a sad fact of life today that pocketable items often "walk." Tiny units have other problems, too. They don't leave room for reasonably long-life batteries or various power options. Likewise, they become harder to use because their readouts are small and the knobs or other controls don't suit big fingers.

Too large isn't much better either. Many otherwise good DMM's just won't fit in tool kits. Having more space inside a DMM *does* make construction and servicing easier—and it does leave room for integrated storage of probes, cords and accessories. When most of the intended use is on a bench with line power, compactness becomes less vital. Even then, a crowded test setup isn't helped by adding another space-taker.

Real versatility demands either battery power or provision to permit battery operation.

At Ballantine, we started out with the premise that our DMM would use a dry-cell power source, but would have a low-cost option to let it be powered from the ac line. Why dry cell? Because of the lower initial cost and the ease with which a reliable indication of "remaining life" can be incorporated.

Even with its battery installed, our Model 3/24 weighs less than a probe type DMM. A fresh 9V battery costing less than $2 provides about 300 hours of operation when used 8 hours a day. This figure is based on running the display at normal brightness. Even longer life is possible if the adjustable brightness level is reduced somewhat (the LED readout draws more current than all the rest of the DMM circuitry).

Ideally, a primary battery would have built-in means for telling how much useful life is left.

Lacking that, we built such an indicator into our DMM. It's not a battery voltage indicator, but instead monitors the peak current delivered by the battery. The reading is made directly proportional to the remaining useful life, with a fresh new battery reading 1000 and one at the end of useful life reading 650. This helps you avoid getting caught with a dead battery, and lets you buy a replacement just before it is needed. It also lets you check the new battery to see if it really is fresh stock.

Not to knock nickel-cadmium batteries, but you should keep in mind that their state of charge is difficult to check. Their voltage remains nearly constant until full discharge, then drops off swiftly. With nickel-cadmiums, you can't be sure of a full day's operation because there is no satisfactory way to monitor the amount of charge remaining. Also, they should be recharged before reaching a full-discharge condition. Therefore, devices using them should provide automatic shutoff for best battery life.

Further, nickel-cadmium batteries have a finite service life of perhaps 500 charge/discharge cycles. They cost several times as much as carbon-zinc throwaway ones and have a poorer weight-to-energy ratio.

When considering overall cost, you'll do well to remember that a DMM is a tool that must always be ready.

At today's labor rates, a single day of down time can easily add up to the price of a DMM.

Battery powering gives complete isolation from the power line with its noise and its grounded reference. You can use a battery operated DMM practically anywhere with safety—even when working around grounded metal machinery, down a manhole, or atop a light pole.

Safety, both for the user and the instrument, should have full attention when designing a DMM.

From the standpoint of user protection, we couldn't have made our Model 3/24 safer to use if it cost $10,000!

In our instrument, a plastic case designed without any external grounded parts, plus the use of plastic switch shafts and knobs, gives full electrical isolation between the DMM and the user. This assumes particular importance when you must make measurements while standing on wet or metal surfaces.

Another safety point is the deliberate limiting of ac voltage measurements to 500V. That covers the 440V lines, and to have gone higher would have offered more potential hazard than value for most users. A fact sometimes forgotten, with fatal consequences, is that ac power lines have very low impedance so can deliver a lethal shock to the careless operator. High-voltage dc sources can be equally hazardous, but often have high enough impedance to give some protection.

Meter safety, as distinguished from user safety, demands built-in overload protection. We provide protection for continuous overloads to 1 kV dc (except 350V on the 1000 mV dc range) on dc voltage ranges; to 500V rms (except 350V rms of a sine wave on the 1000 mV ac range) on ac voltage ranges and to ±10V (dc or ac rms) on ohms ranges. Fuses protect both the ammeter ranges (1.6A) and the ohmmeter ranges (100 mA).

Both meter and user can enjoy considerable protection when an optional "dc-output" line powering device is used. Because the one we offer is literally a dc power supply on a wall plug (only the low-voltage dc goes to the DMM), this UL-listed power source gives good isolation. It makes our DMM safe to use in stringent applications such as those found in hospitals. Using this power source, the DMM can be operated off ground to 1000V dc or 600V ac between either of the instrument terminals and ground.

It adds cost to provide a DMM with the ability to withstand high voltages, so this area always represents a compromise between cost and the degree of overload protection provided. There is *no* compromise with safety.

Wanted: a big, highly readable display that draws no current and works in any ambient light! Reward.

Jokes aside, there isn't any such animal. We favor LED's for small multimeters because of their long life, low price, compatibility with battery operation and ability to operate under any practical ambient conditions. The orange ones introduced recently have the advantage of being more efficient than red, as well as easier on the eyes. Consequently, we may shift to them soon.

Readout power savings have a big effect on overall power drain (because the readout consumes the greater part of the total current). We omitted the "1" in the display for this reason, and also provide front-panel control of display brightness. The control gives the user the option of running the display with full brightness, or cutting brightness down to levels that are adequate and that conserve battery current. It's a nicety, but worth the cost.

To prevent reading errors when an overload is applied, we make the left-hand readout digit indicate it by flashing.

Some DMM manufacturers employ liquid-crystal readouts. These have both strong and weak points when used in a battery-operated DMM. On the good side is very low-current drain. Unfortunately this type of readout does not generate light, but merely transmits or reflects it—so without auxiliary lighting it only has value in well-lit situations. Back-lighting solves that problem, but the battery drain goes up to about the same as with LED's. Another drawback in using liquid crystals is their limited operating temperature range (as compared to LED's).

Buy enough range and accuracy, but don't overdo it or the price tag will hit you hard.

General-purpose analog multimeters traditionally have been devices with from 1 to 5% reading accuracy on voltage and current. They were poorer than that on ohms, where a nonlinear scale made interpolation difficult.

I believe a low-cost DMM should span, at least, from 1 to 1000V F.S. on dc, 1 to 500V rms F.S. on ac, 100 μA to 1000 mA F.S. each on dc and ac and 100Ω to 10 MΩ F.S. on ohms. Leaving out any decade range could only cut the price a nickel or dime, so isn't justified by cost. Accuracy should at least equal that of analog multimeters, but, of course, generally will be superior for resistance measurements.

One other point of note—there should not be more than 1V drop by any of the current ranges. Of course, the less the better.

Eventually I expect DMM's will reach the same basis that currently exists for most analog multimeters—they'll either be considered as "throwaway" items, or you'll do your own fixing.

We also can expect to see true-rms reading low-cost DMM's. They definitely are coming, but they won't emerge until chips are available at low cost. A similar parallel can be found in the history of pocket calculators.

Perhaps the best approach to take when you're about to select a low-cost DMM is that of the "devil's advocate." Take a full cost-of-ownership look at the candidates, and avoid the temptation to overbuy capability just to have it in case it's needed.

First, be sure you know whether a digital or an analog multimeter will serve you best.

Second, fight down any impulse to purchase super accuracy. It's available, but for a price. If you've always been able to do O.K. with 2% measurements it's likely that a 1% DMM will be sufficient.

Third, be sure your choice reflects such considerations as the ease of servicing, the degree to which the instrument has been goof-proofed, the convenience provided by a minimum number of test leads, and warranty and service provisions.

Today's low-cost DMM's serve a real need for greater ease and convenience of measurement, and do so at prices that compete directly with analog versions. Choose wisely and you'll get your money's worth. □

Author's biography

Fred Katzman, President of Ballantine Labs., has an extensive background in instrumentation. His previous positions include 13 yrs. with Dumont Labs., as well as a term as Director of Instruments at Monsanto Electronic Instruments. He received his BSEE from CCNY and his MS from Stevens Institute of Technology, and is a registered Professional Engineer in NY.

Who makes low-cost DMM's?

To help you obtain more information on units priced below $325, we've listed below most of the companies currently selling them. A few prices may have increased—and some models may have changed—by the time you refer to this list.

Ballantine Laboratories, Inc., **Circle No. 85**
Box 97, Boonton, NJ 07005
Model 3/24, $195 Phone(201)335-0900.

Dana Laboratories, Inc., **Circle No. 86**
2401 Campus Dr., Irvine, CA 92664
Model 2000 (Danameter), $195 Phone(714)833-1234.

Data Precision Corp., **Circle No. 87**
Audubon Rd., Wakefield, MA 01880
Model 134, $189; Model 245, $295 Phone(617)246-1600.

Data Technology Corp., **Circle No. 88**
2700 Fairview Rd., Santa Ana, CA 92704
Model 20, $269; Model 21, $269 Phone(714)546-7160.

B & K Precision, Div. Dynascan Corp., **Circle No. 89**
1801 W. Belle Plaine Ave., Chicago, IL 60613
Model 280, $170; Model 282, $200 Phone(312)327-7270.

John Fluke Mfg. Co., **Circle No. 90**
Box 7428, Seattle, WA 98133
Model 8000A, $299 Phone(206)774-2211.

Heath/Schlumberger Instruments, **Circle No. 91**
Benton Harbor, MI 49022
Model 4440, $250; Model 4444, $250;
Model SM-600, $120 Phone(616)983-3961.

Hewlett-Packard, **Circle No. 92**
1501 Page Mill Rd., Palo Alto, CA 94306
Model 970A("Probe DMM"), $310 Phone(415)493-1501.

Keithley Instruments, **Circle No. 93**
28775 Aurora Rd., Cleveland, OH 44139
Model 168, $299 Phone(216)248-0400.

Non-Linear Systems, Inc., **Circle No. 94**
Box N, Del Mar, CA 92014
Model LM-4, $227 Phone(714)755-1134.

Simpson Electric Co., **Circle No. 95**
853 Dundee Ave., Elgin, IL 60120
Model 360, $295. Phone(312)695-1121.

Tekelec, 31829 W. La Tienda Dr., **Circle No. 96**
Westlake Village, CA 91361, Phone(213)889-2834.
Model TA 355, $289; TA 356, $289; TA 357, $179

T.R.I. Corp., **Circle No. 97**
505 W. Olive Ave., Sunnyvale, CA 94086
Model 6354, $289; Model 6355, $279 Phone(408)733-9080.

United Systems Corp., **Circle No. 98**
918 Woodley Rd., Dayton, OH 45403
Model 2110, $219 Phone(513)254-6251.

Valhalla Scientific Inc., **Circle No. 99**
7707 Convoy Ct., San Diego, CA 92111
Model 4440, $299 Phone(714)277-2732.

Weston Instruments, Inc., **Circle No. 100**
614 Frelinghuysen Ave., Newark, NJ 07114
Model 4440, $269; Model 4442, $295 Phone(201)243-4700.

Designer's Guide to: Audio and converter transformers

To get the most out of the versatile magnetic transformer, textbook theory must be closely coupled with updated practical information.

W. Dull, Bourns, Inc.; **Dr. A. Kusko** and **T. Knutrud,** Alexander Kusko, Inc.

Basic circuit building blocks are often ignored in technical literature, trampled by the thundering stampede of articles describing the leading edge of advanced technology. Yet, few circuit designers can ply their trade without considering discrete components; e.g., resistors, inductors, capacitors, transformers, etc. Nor does technology pass these components by. Manufacturers are constantly improving their products. Therefore, designers have a constant need for updated component information.

Recognizing this need, we will present in this and future articles a state-of-the-art tutorial on magnetic components. Our aim is to provide the reader with an improved understanding of these versatile devices. Circuit examples consistent with today's technology will detail basic selection process considerations. Our discussion of audio and converter transformers follows.

Audio transformers

Audio transformers interconnect circuit stages, match transducer impedances to amplifiers, and carry out functions of isolation, signal polarity inversion and level change. Miniaturized audio transformers are designated as input, interstage, driver, isolation or output transformers, and are designed for audio, carrier and broadband applications in the 20 Hz to 500 kHz spectrum.

Selection considerations

An audio transformer is selected on the basis of circuit function, frequency band, source and load impedance, and power or voltage level. Additional factors include size, insertion loss, distortion, dc sensitivity, balance and shielding. Parameters are selected by calculation and/or test in a prototype circuit.

The circuit function determines whether the primary and secondary windings are single-ended or center-tapped, the requirements for balance and shielding, the presence of direct current and allowable distortion. Signals to be passed by the transformer must fall between the half-power frequencies, f_2 and f_1. These frequencies shift upward as a transformer is miniaturized, but maintain a ratio $f_2/f_1 \approx$ 500 to 1000. Phase shift between input and output signals may limit the useful pass band to a narrower range. In microminiature transformer applications, f_1, the lower half-power frequency, is usually critical.

The turns ratio of the classical transformer is selected to match the load impedance to the source impedance. Maximum power transfer is the object.

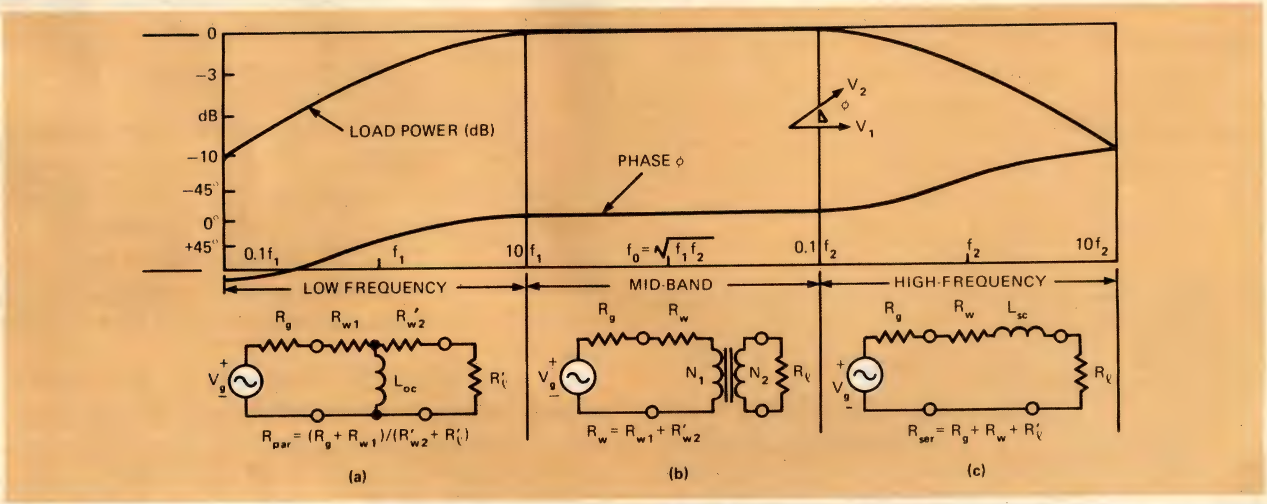


Fig. 1—Audio transformer circuit models vary depending on whether you're considering device characteristics at low, mid or high frequencies. Increasing the driving voltage or allowing an unbalanced dc component in either winding increases distortion, reduces inductance L_{oc} and raises f_1 (thus decreasing bandwidth, because f_2 remains constant).

In actual applications, matching is required for filter, transmission-line and other terminations, but deliberate mismatch is used for input and output transformers to reduce distortion. How? A transistor stage's input resistance varies with signal level. Therefore, to reduce distortion, the turns ratio of an input transformer is selected so that the reflected load resistance is minimized with respect to the source resistance. Likewise, the turns ratio of an output transformer is selected to place the ac load line at the most linear portion of the amplifier's characteristics.

An audio transformer's power rating is defined as the maximum power that can be delivered at a given frequency to the rated load resistance within prescribed values of distortion and insertion loss. The frequency specified usually is near f_1. Load power equals the product of the secondary voltage V_2 and current I_2, where the voltage is proportional to the magnetic flux density B_m and frequency f.

As a transformer is driven harder, both B_m and the magnetizing current increase. The magnetizing current rises rapidly as B_m approaches saturation, producing distorting voltages in the source and primary winding resistances. This distortion sets the maximum voltage, while the insertion I^2R loss of the windings sets the maximum load current.

In selecting an audio transformer where the load impedance is not known, the V_2 and I_2 requirements should be determined independently at a specific frequency and distortion. Then the power and impedance for the transformer can be calculated. The maximum voltage at the lowest frequency is limited by the turns and core area; the turns are limited by the finest wire that can be wound physically.

Design characteristics

The transformer as a circuit element is characterized by its winding resistances, short-circuit inductance L_{sc}, open-circuit inductance L_{oc}, and turns ratio. As a device, it is characterized by a magnetic core and two or more windings. Magnetic core size and material sets the half-power frequencies, as well as the V_2I_2 power rating for prescribed distortion and insertion loss. The windings set the turns ratio and the maximum voltage and current of each winding. Most transformers operate below the power rating and frequently with turns ratios not consistent with matched impedances.

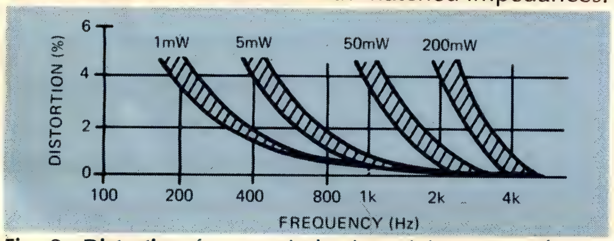


Fig. 2—Distortion for a typical microminiature transformer (e.g., a Bourns Model 4210) decreases with increasing frequency, increases as power increases.

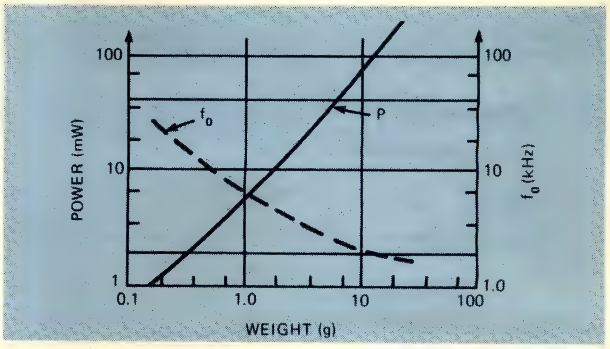


Fig. 3—Miniaturizing an audio transformer changes its electrical characteristics, as these typical values for commercial audio transformers show.

For convenience, the frequency band is divided into a mid-band, high-frequency and low-frequency region **(Fig. 1)**. The center of the mid-band is the geometric mean of the half-power frequencies, $\sqrt{f_1f_2}$, sometimes called the reference frequency. In the mid-band region, the transformer can be modeled by its winding resistances R_{W1} and R_{W2}, plus an ideal transformer with the turns ratio of the actual device. The turns ratio is calculated to obtain the required voltages or to present the desired impedance to the source or load.

In a perfectly matched lossless transformer ($R'_\ell = R_g$), the load power $P_{max} = V^2_g/4R'_\ell$ and the insertion loss equals zero. In an actual transformer, winding resistances and core loss reduce the load power from the matched value. The dB insertion loss is given by 10 log P_ℓ/P_{max}. At reference frequency f_0 the core loss can be neglected, so the dB insertion loss is 20 log $2R'_\ell/R^2_{ser}$. The 0 dB level in **Fig. 1b** includes the effect of the mid-band insertion loss. In miniature transformers, winding resistances are about 10% of the source and load impedances, producing about 0.8 dB insertion loss.

In the high-frequency region, leakage inductance becomes significant and the transformer can be modeled as shown in **Fig. 1c.** The leakage inductance is approximately the short-circuit inductance L_{sc}. The upper half-power frequency f_2 is defined where the leakage reactance is equal to the series resistance R_{ser}. Here the phase shift is −45° and the transmission is down −3 dB from the mid-band level. Frequency f_2 can be raised as a consequence of raising f_1, by tightening the coupling of the windings, by reducing turns, and by increasing the load resistance R_ℓ at the expense of reducing the load power.

For microminiature transformers, the low-frequency region is critical because miniaturization favors high-frequency operation. The transformer can be modeled in terms of the magnetizing or open-circuit inductance L_{oc} and the equivalent parallel source and load resistance R_{par} **(Fig. 1a)**. Lower half-power frequency f_1, where the magnetizing reactance equals R_{par}, can be lowered by using more turns of smaller wire at the expense of insertion loss, or by increasing the core and transformer size. These factors also reduce frequency f_2, so the f_2/f_1 ratio remains constant.

To lower f_1 and simultaneously increase the ratio f_2/f_1 (bandwidth), the designer must employ better core material such as Supermalloy, working it at higher values of permeability and flux density. Design and application factors can also shift the f_1 and the f_2/f_1 ratio. For example, increasing the driving voltage or allowing an unbalanced dc component in either winding raises the distortion, reduces L_{oc} and raises f_1, without also raising f_2.

Microminiature transformer distortion decreases with increasing frequency. At a given frequency, it increases with power. **Fig. 2** shows this relationship.

As an audio transformer is miniaturized, not only does it become smaller and lighter, but its electrical parameters change. For a transformer of linear dimension ℓ, the following effects occur as ℓ is reduced:

1. The volume and weight decrease as ℓ^3.
2. The power rating at the lower half-power frequency decreases about as ℓ^3.
3. The winding resistances increase as $1/\ell$.
4. The mid-band frequency and upper and lower half-power frequencies increase as $1/\ell$.

Fig. 3 shows typical values for commercial audio transformers.

Design examples

1. A microminiature transformer has 1:1 turns ratio for matching a 1 kΩ source to a 1 kΩ load resistance at 25 mW mid-band level. The winding resistances are 115 Ω each, the half-power frequencies $f_1 = 2$ kHz, $f_2 = 500$ kHz. Find the insertion loss, and the inductances L_{oc} and L_{sc} for which the transformer must be tested.

The insertion loss, assuming the core loss is negligible, equals:

$$\text{loss} = \frac{2R'_\ell}{20 \log R_{ser}} = 20 \log 0.9$$
$$= -1.0 \text{ dB}$$

Inductance L_{oc} is obtained from f_1:

$$L_{oc} = \frac{R_{par}}{2\pi f_1} = \frac{1115/2}{2\pi \times 2000} = \underline{44 \text{ mH}}$$

Inductance L_{sc} is obtained from f_2:

$$L_{sc} = \frac{R_{ser}}{2\pi f_2} = \frac{2230}{2\pi \times 500{,}000} = \underline{0.71 \text{ mH}}$$

2. Select the most suitable catalog microminiature transformer for the circuit of **Fig. 4** to provide $V_2 = 1.5$V rms, $I_2 = 15$ mA rms, at 1000 Hz, with a winding power insertion loss of 1.2 dB from the ideal matched value.

The load appears as a resistance $V_2/I_2 = 100\,\Omega$ and power $V_2 I_2 = 22.5$ mW. For 1.2 dB insertion loss, the winding resistance R_w reflected to the primary is given by:

$$\text{loss} = 20 \log \frac{2R'_\ell}{R_{ser}} = 20 \log \frac{2 \times 500}{1000 + R'_w} = -1.2 \text{ dB}$$

$$\frac{1000}{1000 \times R'_w} = 0.87$$
$$R'_w = 150\,\Omega$$

The turns ratio for matching to the load is $N_1/N_2 = \sqrt{650/100} = 2.55$.

Bourns transformer 4210-0018 comes close to the required parameters: turns ratio = 3.16:1; impedance ratio = 500:50 Ω; winding resistances = 55.6 Ω; and rated power of 50 mW at 1000 Hz. The maximum voltage V_2 at 1000 Hz is $V_2 = \sqrt{P \times R} = \sqrt{50 \times 0.05} = 1.58$V rms. Total winding resistance reflected to the primary is $R'_w = 115\,\Omega$ and the insertion loss from the matched value is:

$$\text{loss} = 10 \log \frac{\text{actual load power}}{\text{matched load power}}$$
$$= 10 \log \frac{V_g^2 \times 1000/\,(1615)^2}{V_g^2/4 \times 500}$$
$$= 10 \log 0.775 = \underline{-1.1 \text{ dB}}$$

Thus, the transformer is satisfactory in both voltage rating and insertion loss.

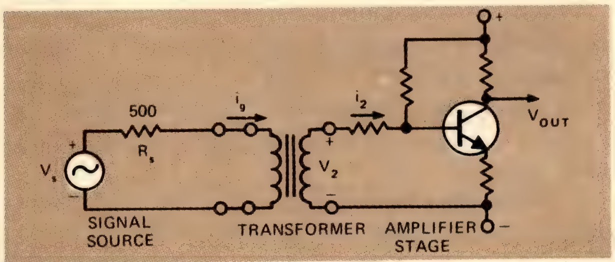


Fig. 4—Insertion loss and voltage rating are critical factors in the selection of the optimum input transformer for this amplifier application.

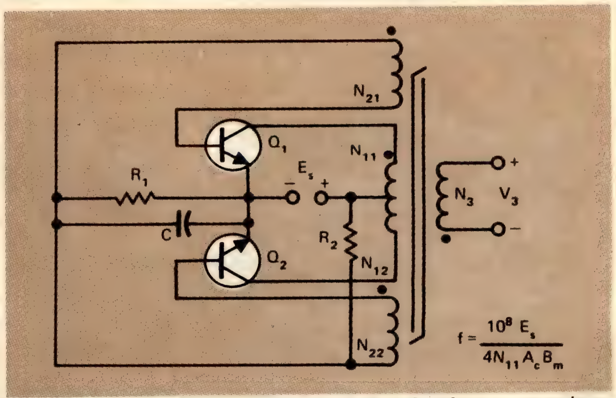


Fig. 5—The transformer saturation flux level, source voltage E_s and the number of turns N_{11} determine the switching frequency in this basic dc-to-ac square wave inverter.

Converter transformers

Transformers are used in a variety of circuits designed to invert dc-to-ac power. Often the ac is rectified for dc transformation and dc circuit isolation. In a typical relatively low power circuit, the transformer provides feedback for switching the transistors and delivers power from a secondary winding. The core flux saturation level determines the converter frequency and the transformer usually is best designed with square-loop core material. High power converters, or converters operating at ultrasonic frequencies, use a separate output transformer that operates well below saturation to reduce core losses. An additional square-loop transformer or inductor establishes the operating frequency.

Selection considerations

It is necessary to understand the principles of operation of the inverter for proper transformer selection. **Fig. 5** shows a circuit diagram of a simple and much used dc-to-ac (square wave) inverter. Its transformer operates between $\pm B_m$ (saturation) levels on a major B-H loop and provides transistor (base) drive by means of equal secondary windings, N_{21} and N_{22}.

Assuming that Q_1 is conducting and Q_2 is open, voltage E_s will be placed across primary winding N_{11}. Q_1 is driven into saturation by the voltage across N_{21}; Q_2 is kept open by the N_{22} voltage. The transformer core flux will change with time according to the equation $N_{11} d\phi = E_s dt$ along a hysterisis loop marked (1) in **Fig. 6.** The output voltage is then positive **(Fig. 7).**

When the core saturates at $+B_m$, the magnetizing current quickly rises to a point where Q_1 no longer can stay in saturation, or when $I_c = h_{fe}\ I_b$. At this point the voltage across Q_1 begins to increase, consequently reducing I_b and moving Q_1 further out of saturation.

A regenerative transient is now set into motion which reverses the voltage across the windings. Thus, Q_2 is driven to saturation. The direction of flux change then reverses, going along (2) in **Fig. 6.** The output voltage reverses as shown in **Fig. 7.** The same process now repeats involving Q_2, N_{12} and N_{22}.

The switching frequency, f, is determined by the transformer saturation flux level B_mA_c, the source voltage E_s (less drop across Q) and the number of turns N_{11}; $f = 10^8\ E_s/4N_{11}\ A_cB_m$.

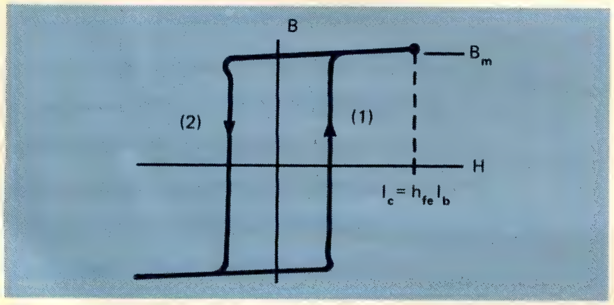


Fig. 6—Square-loop core material is recommended for relatively low power inverter transformers.

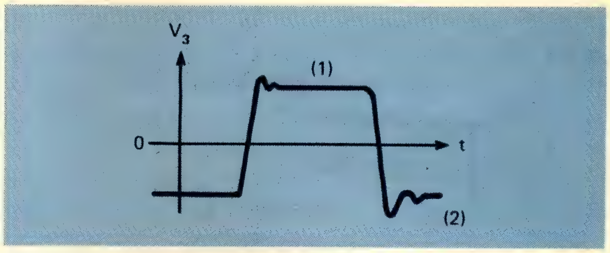


Fig. 7—Slopes of output waveform and duration of overshoots increase as the saturated inductance of the converter transformer increases.

Operating frequency is often dictated by the application, but in dc-to-dc converters a relatively high frequency is desirable to reduce size and weight of all components. However, the core losses and temperature rise increase with frequency, while the heat dissipation area is reduced with size. Thus, the optimum choice of frequency must be made by tradeoffs of transformer size, weight, temperature rise and cost. **Fig. 8** shows the weight and temperature rise vs. frequency of transformers designed for a 100W inverter. Transistor switching losses will also increase with the operating frequency **(Fig. 9).**

Design characteristics

The VA rating of a square-wave inverter transformer is proportional to the product of the core area A_c and the window area A_w:

$$A_wA_c = \frac{3.05 \times \text{VA} \times \text{J (CM/A)}}{\text{f (Hz)} \times \text{Bm (G)} \times 0.12}\ (\text{in.}^4)$$

Manufacturers such as Arnold Eng. Co. list cores by the A_wA_c value. By using current density $J =$ 400 to 500 CM/A for the 1 to 100 VA range and $B_m =$ 14,000G for the 50-50 Ni-Fe core material, the designer can estimate the size of the transformer.

Converter transformers must exhibit a relatively sharp saturation knee with a minimum of residual inductance in the saturated state. There are two main reasons for this: 1. The time spent in saturation, and consequently the switching losses (primarily in the power transistors), increase with inductance. 2. Higher saturated inductance increases the waveform slopes and duration of overshoots (undesirable especially in dc-to-dc converter applications).

Practically all feedback-type converter transformers requiring a square B-H loop are wound on toroidal tape cores using 50% Ni-50% Fe (Deltamax); 80% Ni (Supermalloy); and ferrites. Tape cores are used up to 20 to 50 kHz; ferrite cores at higher frequencies. Since the cores must operate at saturation, core loss rises steeply with frequency. Separately driven converters basically use output transformers operating below B_m and at lower core loss densities.

Although core losses in square-loop material generally are lower than in silicon steels, these

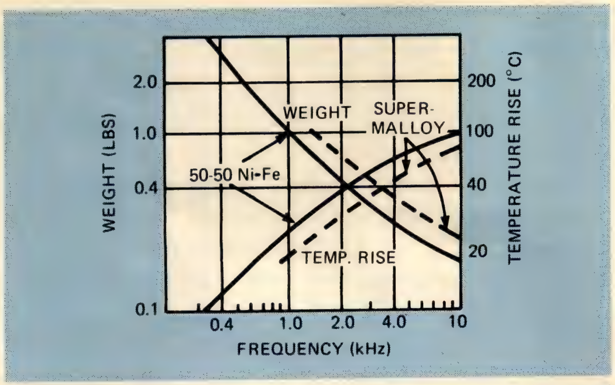


Fig. 8—Tradeoffs of transformer size, weight, temperature rise and cost must be made to determine the optimum transformer. These curves are for an inverter with a 100W output (dissipation = 4W).

losses play a very important part in converter transformer design. The dependence of the core losses with the frequency of two popular core materials is given in **Fig. 10.** These curves fairly well bracket the core losses for most other square-loop materials. Silicon steels have much less sharp saturation knees and higher core losses. Therefore, they're usually limited to 60- to 400-Hz operation, or in applications such as output transformers where flux level is well below saturation.

Since the frequency of an inverter, as in **Fig. 5,** is inversely proportional to the core saturation level, any change of B_m produces a frequency shift. Temperature coefficients of the Ni-Fe alloys are approximately −0.07%/°C. Better frequency stability can be obtained with Si-Fe core material. However, for most applications other than voltage-to-frequency converters, frequency stability is of little consequence.

The feedback windings, which provide base-current drive for the switching transistors, must be carefully designed in an effort to minimize drive losses. But at the same time, they must provide sufficient drive for all inverter loading conditions. It is common practice to provide a 2:1 base current overdrive, at which level the base-to-emitter voltage is typically 1.5 to 2V. To counteract variations with temperature (and to provide a divider for transistor bias) a series resistor is used with a voltage drop approximately equal in value. Feedback windings, therefore, are wound to yield 3 to 4V. The current required for the base is typically less than 0.1 of the output current for the 2:1 drive requirement. Thus, base drive losses should be no higher than $(0.1) \times (4/12) = 3\%$ for an inverter operating on 12V dc. For 24V dc operation the losses should be about 1.5%.

Design examples

DC-to-DC converter. Determine the transformer parameters for a dc-to-dc converter that must operate from a 12V supply and deliver 100V at 1A. The circuit is that of **Fig. 5** with a rectifier and filter capacitor on the output terminals. Assume an overall efficiency of 90%.

In the design of this converter three requirements are of foremost importance: (1) the inverter frequency should be high to reduce size, weight and cost of both transformer and output filter; (2) the switching time should be short to minimize transistor switching losses and again reduce the necessary filtering; and (3) the circuit should include components to speed up the transistor switching delay, and to assure that the inverter will start when dc power is applied.

Requirement (1) leads the designer into the compromise of core weight, temperature rise and cost of higher grade material **(Fig. 8).** We will select a 50% Ni-50% Fe (Deltamax) core operating at 400 Hz. The switching time with fast transistors depends primarily on the saturated inductance of the transformer. To check on requirement (2), the time can be estimated from $T_{sw} = i_b h_{fe} L_s/V_{cc}$, where i_b is the base drive current, h_{fe} the transistor gain, L_s the saturated inductance of the $N_{11} =$ winding, and V_{cc} the dc voltage.

For a 100W converter with a full load transistor current of 10A at $V_{cc} = 12V$ operating at 400 Hz, typical numbers are $T_{sw} = 1 \times 20 \times 20\ \mu H/12 = 33\ \mu sec$. To meet requirement (3), the switching speed can be shortened significantly by the addition of capacitor C in **Fig. 5.** The optimum value of C must be determined experimentally, but the initial choice should be where the R_1C product equals 1 to 2% of the inverter period.

The core is selected from:

$$A_wA_c = \frac{3.05 \times 105 \text{ VA} \times 500 \text{ CM/A}}{400 \text{ Hz} \times 14{,}000 \text{ G} \times 0.12} = 0.24 \text{ in.}^4$$

A suitable 4-mil tape Deltamax core has dimensions, 1.25-in. i.d., 2.0-in. o.d., 0.75-in. ht., $A_c = 1.633$ cm² net, $A_w = 1.024$ in.², $A_wA_c = 0.288$ in.⁴.

The secondary turns, N_3, are:

$$N_3 = \frac{100\text{V} \times 10^8}{4 \times 400 \text{ Hz} \times 1.633 \text{ cm}^2 \times 14{,}000 \text{ G}} = 273 \text{ turns}$$

The wire area must be about 1A × 500 CM/A = 500 cmil. Per-unit occupancy of the window

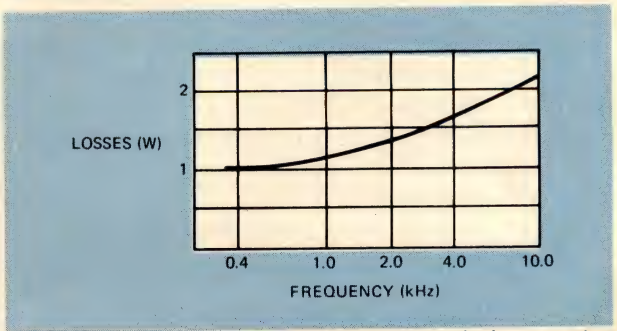


Fig. 9—Transistor switching losses increase with the operating frequency. This curve shows the losses for each device in a typical 100W inverter.

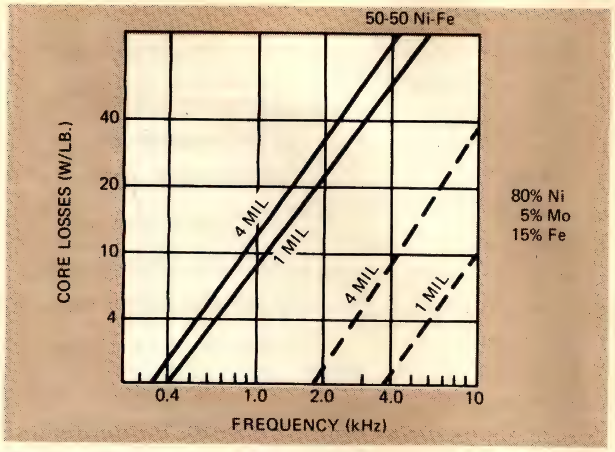


Fig. 10—Changes in operating frequency produce corresponding changes in core losses. These curves, while drawn for specific alloys, fairly well bracket the core losses for most other square-loop materials.

by the secondary winding copper is 500 CM × $\pi/4 \times 10^6/1.024$ in.^{2} = 0.038. Primary windings N_{11} and N_{12} and feedback windings N_{21} and N_{22} are designed in the same manner. The per-unit target for copper "fill" of the window for all windings is 0.28.

To obtain sufficient drive, the $i_b h_{fe}$ product should exceed that required to hold the transistor in saturation by a factor of 1.5 to 2. With N_{21} and N_{22} windings giving approximately 4V, this requirement then determines the value of R_1. Addition of resistor R_2 provides a bias on the transistors of about 0.7V and assures conduction of the transistors when dc power is applied.

DC-to-frequency converter. Select the parameters for the transformer in the converter of **Fig. 11.** This circuit converts a dc signal to a proportional frequency signal, using an operational amplifier to obtain the dc power for the converter. The maximum dc voltage to be converted in this circuit would typically be 25V.

Since the drop across the converter's transistors is about 0.5V, this circuit can provide linear conversion over a 20:1 range with an accuracy of better than 2% of maximum frequency. Assume that the converter must operate from 50 to 1000 Hz and that it must deliver 1W at the maximum frequency. Variation of the frequency with temperature would result in approximately +0.07%/°C change in frequency when 50% Ni-50% Fe cores are used (Si-Fe cores do not lend themselves well to this application). This variation can be compensated for by the use of temperature sensitive resistors, such as a thermistor **(Fig. 11).**

The core is selected by the A_wA_c product from:

$$A_wA_c = \frac{3.05 \times 1\ \text{VA} \times 400\ \text{CM/A}}{1000\ \text{Hz} \times 14{,}000\ \text{G} \times 0.12} = 0.00073\ \text{in.}^4$$

The dimensions of a suitable Deltamax 2-mil tape core are, 0.437-in. i.d., 0.563-in. o.d., 0.125-in. ht., 0.0037 lb. The core loss density is about 10W/lb. at 1000 Hz, or a core loss of 0.0037 lb. × 10W/lb. = 0.037W, which is acceptable compared to the 1W converter rating.

Converter with separate output transformer: Specify the output transformer for the 100W, 50-kHz converter of **Fig. 12.** The output transformer is operated below saturation to limit core loss and temperature rise. The small input transformer provides the transistor drive signals and sets the frequency by saturation. Assume that to limit the temperature rise the core loss must not exceed 1W.

Two core materials will be considered: 50% Ni-50% Fe (Deltamax) and 80% Ni (Supermalloy). The parameters are as follows:

No.	Material	B_m	Core Loss Density
(1)	(50% Ni-56% Fe)	1.5 kG	30W/lb.
(2)	(80% Ni)	3.0	40

	A_wA_c	Core Wt.	Core Loss
(1)	0.018 in.^{4}	0.033 lb.	1W
(2)	0.009	0.017	0.7

The cores are both 1-mil tape, 1.0-in. i.d., 1.25-in. o.d., 0.25-in. ht. for core (1), 0.125-in. ht. for core

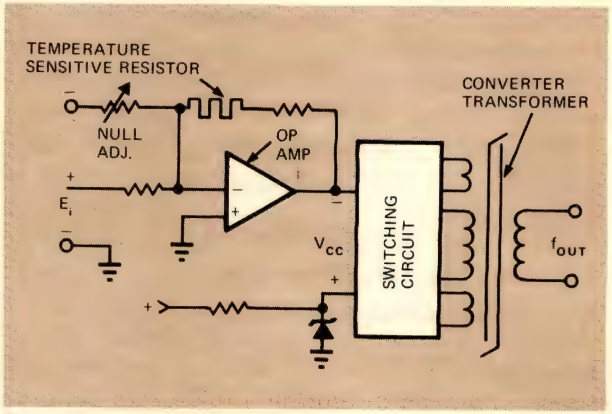


Fig. 11—In this voltage-to-frequency converter, the op amp provides the dc power, while the temperature-sensitive resistor compensates for changes in the core saturation level caused by varying ambients.

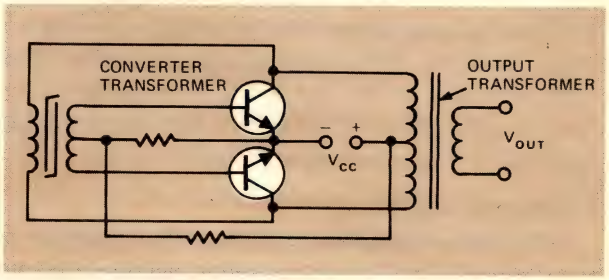


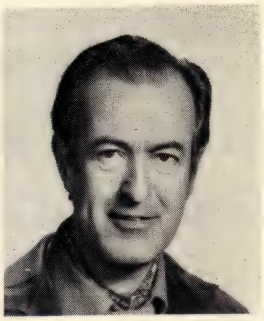
Fig. 12—To limit core loss and temperature rise, the output transformer in this 100W, 50-kHz converter operates below saturation. Small square-loop input transformer provides transistor drive signals and sets the operating frequency by saturation.

(2). They are relatively small and may not significantly affect the overall transformer size and cost. With these cores operating at 50 kHz and below 3 kG, the designer must also consider a ferrite core. □

Authors' biographies

William Dull, vice president and general manager of Bourns Pacific Magnetics Corp., Romoland, CA, has overall responsibility for all magnetics-related products for Bourns, Inc. He attended Lehigh Univ. and is a member of the IEEE and AMA. Bill enjoys sailing and philately.

Dr. A. Kusko is president of his own consulting firm, Alexander Kusko, Inc., and is also a Lecturer at M.I.T. He received his BSEE from Purdue; his SM and ScD degrees in Electrical Engineering from M.I.T., and is a member of Sigma Xi, Tau Beta Pi and Eta Kappa Nu. A Registered Professional Engineer, Dr. Kusko has been granted 14 patents. He reports that this article represents "the culmination of 25 years of consulting and development work on magnetics, including numerous patents, articles and a book."



Thorleif Knudtrud has been a senior consultant with Alexander Kusko, Inc. since 1970. He's an MIT man (BSEE, MSEE), a member of the IEEE and NIF, and has been granted two patents. Thor, who has designed and developed magnetic circuits since the early days of magnetic amplifiers, feels certain that magnetic circuit design still has and will continue to have a very important mission in electronics.

References

Dr. A. Kusko and T. Wroblewski "Computer Aided Design of Magnetic Circuits," M.I.T. Press, 1969.

"The theory and application of transformers and inductors," BPMC, a Division of Bourns, Inc., Romoland, CA 92380.

A program loader in a briefcase!

STR-LINK™

STR-LINK is the first portable program loader to give you so many advantages in one package.

It's compact enough that you can carry it anywhere.

And it's versatile enough that you can use it almost anywhere. STR-LINK has a built-in interface that makes it compatible with line printers, MODEMs, mini-computers, CRT's, programmable controllers and send/receive printing terminals.

The key to STR-LINK's performance is our patented Speed-Tolerant Recording, a single-track, self-clocked technique that eliminates the need for an ultra precise drive mechanism.

Other features include:

- 20 MA current loop or RS232C.
- Read/Write capability at 110, 150, 300, 600 and 1200 baud.
- Ability to write at one speed, play back at that speed or any higher.
- 19" Relay Rack-Mount Kit available.

STR-LINK is available through sales offices in over 25 major cities in the U.S. and Canada.

And best of all, it costs as little as $995 in OEM quantities!

For complete information on the most revolutionary program loader ever, write or call today.

ELECTRONIC PROCESSORS INCORPORATED

1265 W. Dartmouth Avenue, Englewood, Colorado 80110
Phone: 303/761-8540 TWX 910-933-0171

For more information, Circle No. 16

Our byte-size brain food for 'little' thinkers:

TRW/Cinch microminiature Dura-Con* connectors

No matter how large your byte, you still have to think "little" to reduce space and weight. That's why TRW/Cinch microminiature Dura-Con connectors offer so much food for thought.

The trim microminiature rectangular series of Dura-Con connectors is available in 9, 15, 21, 37, and 51 positions. Or consider the possibilities in stacking .075" thick Dura-Con strips. Only 33 grams of strips with .050" centers supplies 247 contact positions in a single square inch. Both types are available from TRW/Cinch distributors.

Besides high contact density, the unique Dura-Con design provides highly reliable connections. Each pin contact, formed from precision miniature spring cable of gold-plated 24 gauge copper alloy, provides seven points of peripheral contact with the mating socket wall. Thus continuous mating is assured, no matter what radial forces are applied, from dry circuit to 3 amps.

Also available are TRW/Cinch Dura-Con connectors with #30 AWG contacts on .025" centers in custom configurations. That's up to 1521 contacts in a square inch for those who think much about "little."

For additional information, dial toll-free (800) 645-9201 for the name of your nearest TRW/Cinch sales office. Or write for technical bulletin CD-205 to TRW/Cinch Connectors, an Electronic Components Division of TRW Inc., 1501 Morse Avenue, Elk Grove Village, Illinois 60007; phone (312) 439-8800.

*Trade Name TRW Inc. CC-7502

TRW® CINCH CONNECTORS

For more information, Circle No. 17

CMOS: Opportunities unlimited—*if* you know the basic ground rules

To realize the maximum benefit from CMOS logic, the designer must understand some of the generic properties of this family.

Ken Stephenson, Harris Semiconductor

CMOS contains, what is perhaps the most ideal set of operating characteristics for a logic family. However, the advantages of zero quiescent power, high voltage noise immunity, wide power supply range and high input impedance do not come free. For example, the high input impedance ($10^{12}\Omega$) that increases dc fanout and contributes to low-power consumption comes at the expense of susceptability to static charge damage. If we use proper handling techniques, though, we can minimize such problems caused by static charge. And so it is with the general operating characteristics of CMOS. Strict adherance to a sound set of design ground rules will eliminate problems, and maximize user benefits.

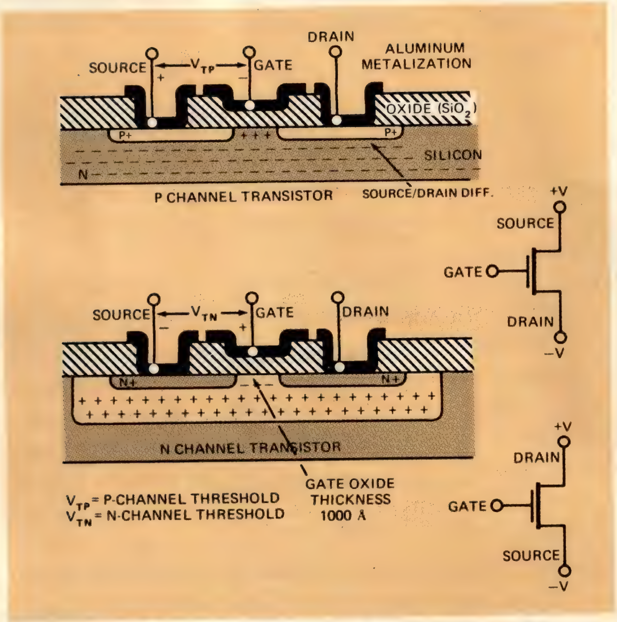


Fig. 1—Application of a negative voltage in excess of one V_{TP} from gate to source, or a positive voltage in excess of one V_{TN} from gate to source of a p-channel or n-channel transistor, respectively, inverts the channel material. This induces a conductive path from source to drain.

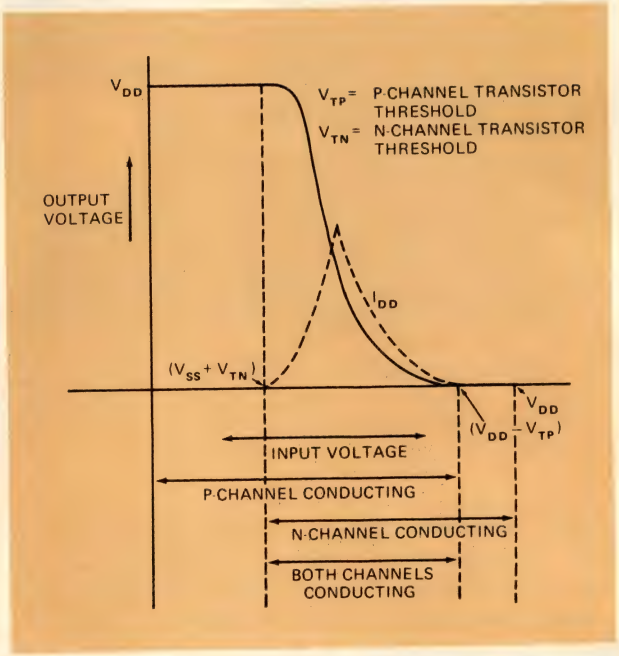


Fig. 2—CMOS voltage transfer curve: Balanced impedances are achieved by choosing correct transistor dimensions.

The MOS transistor

The basic building blocks for all CMOS logic functions are n-channel and p-channel Metal Oxide Semiconductor (MOS) transistors **(Fig. 1).** These devices function as voltage-controlled switches and are capable of bilateral current flow between source and drain.

The heavily doped source and drain diffusions are separated by a narrow gap over which lies a thin-gate oxide and aluminum metallization. In order for the transistors to conduct current from source to drain, we must apply voltage in excess of the threshold from gate to source. The threshold is the voltage that must be exceeded in order to

NONSATURATED OPERATION

$$(V_{GS} - V_T) \geq V_{DS}$$

$$I_{DS} = K \frac{W}{L} [2 \, (V_{GS} - V_T) \, V_{DS} - V_{DS}^2 \,]$$

SATURATED OPERATION

$$(V_{GS} - V_T) \leq V_{DS}$$

$$I_{DS} = K' \frac{W}{L} (V_{GS} - V_T)^2$$

Where:

V_{GS} = Gate-to-Source Voltage

V_{DS} = Drain-to-Source Voltage

V_T = MOS Threshold Voltage

$$K' = \frac{\mu \epsilon}{2T_{ox}}$$

μ = Channel Mobility

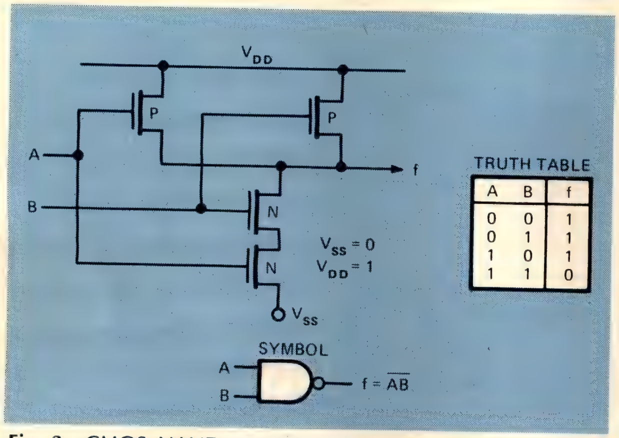
ϵ = Dielectric Constant of the Gate Oxide

T_{ox} = Thickness of the Gate Oxide

T_A = Ambient Temperature, °K

W = Effective Channel Width (Source or Drain Width)

L = Effective Channel Length (Source to Drain Spacing)



A	B	f
0	0	1
0	1	1
1	0	1
1	1	0

Fig. 3—CMOS NAND gate: A multiple input NAND gate can be configured with parallel p-channel transistors and series n-channel transistors in the manner shown here. NAND gates with more than two inputs would require one p-channel/n-channel pair per additional input.

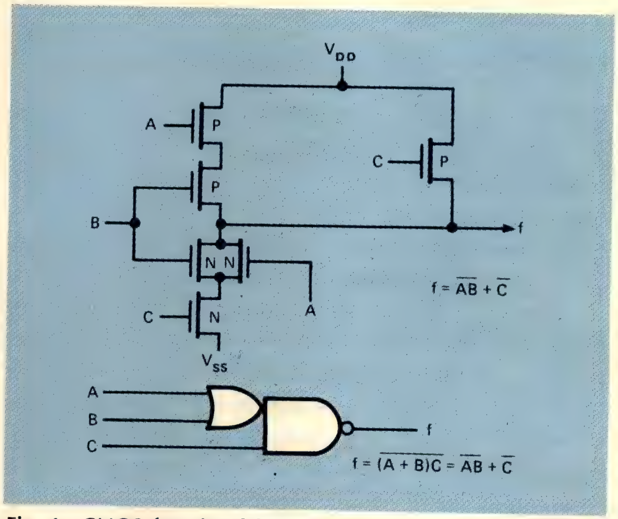


Fig. 4—CMOS functional logic: Implementation of the function $f = \overline{AB} + \overline{C}$ results in a savings of four transistors. The straightforward gate implementation requires 10 transistors, functional logic uses only six.

invert the silicon between the source and drain to form a conducting channel. Increasing the gate-to-source bias beyond the threshold voltage further inverts the material under the gate electrode, increasing conductivity.

The MOS characteristic is represented by two curve segments, an inverted parabola for nonsaturated operation $(V_{GS} - V_T) \geq V_{DS}$ and a straight line for saturated operation $(V_{GS} - V_T) \leq V_{DS}$.

Channel mobility decreases with increasing temperature and is primarily responsible for most temperature dependent performance variations.

From MOS comes CMOS

Virtually any logic function can be performed using parallel/series combinations of n- and p-channel transistors. In addition, complementary MOS structures offer many advantages over circuits using p- or n-channel transistors exclusively. Speed, power, voltage noise immunity, fanout and power supply regulation considerations are all in favor of the system designer. We can easily see the reasons for this, if we understand the basic inverter circuit. We have shown a CMOS inverter voltage-transfer curve **(Fig. 2)** with I_{DD} superimposed over the transfer function. From this diagram we can note the following.

- The inverter threshold centers around the midpoint of the input voltage swing. Proper selection of transistor dimensions results in balanced impedances and an approximately centered gate threshold, regardless of the V_{DD} supply voltage. This factor coupled with the V_{DD} to V_{SS} logic voltage swing is responsible for CMOS's high noise immunity for both logic ONE and ZERO levels.
- We can observe from the I_{DD} curve that no dc current flows when the input voltage is within one threshold voltage of either V_{DD} or V_{SS}. A series current path exists from V_{DD} to V_{SS} only during transitions of the input voltage through the range for which both channels are conducting.

- For CMOS logic to function properly, the difference in supply voltages V_{DD} and V_{SS} must be $\geq$ the sum of the n- and p-channel thresholds. With this condition satisfied, the voltage input/output relationship will be defined as illustrated in Fig. 2.

  For a supply voltage $>$ the threshold sum, there will be overlap in p- and n-channel conduction. This results in a current path as the invertor input passes through the active region where both members of the complementary pair are simultaneously turned on. Voltage division across the pair also results in some rounding of the transfer characteristic. The best case for min. series currents and a square transfer junction occurs with the supply voltage exactly equal to the threshold sum. Under this condition the input switches from one supply extreme to the other, no overlap in conduction will be evident.

These basic operating characteristics also apply to gate and complex logic functions.

On to functional logic

We can implement a NAND gate in CMOS by a series/parallel transistor combination **(Fig. 3).**

Comparing the truth table and circuit schematic, the only way to switch the output to a ZERO level (V_{SS}) is to apply two ONE's (V_{DD}) at the inputs. By doing this we close the series path through the two n-channel devices to V_{SS}. And for other input logic combinations, the series n-channel path is open with one or more of the parallel p-channel devices pulling the output to a ONE level.

The CMOS NOR gate is similar to the NAND function. However the p-channel devices are in series, while the n-channel's are in parallel.

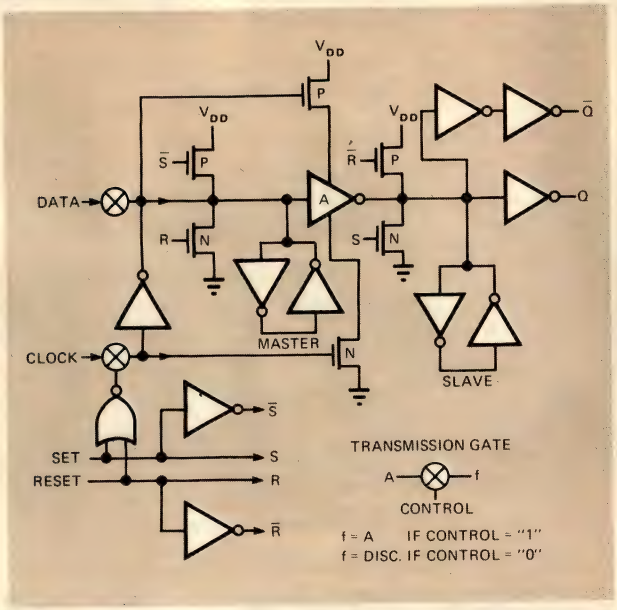


Fig. 5—Master/Slave "D" type flip-flop: This application shows the use of transmission gates to isolate Data and Clock inputs during the appropriate portions of the operating cycle. With Clock a logic ONE level, Data is isolated from the master. With Set or Reset, a One clock is isolated from the internal circuitry.

Functional logic is easily implemented with only a fraction of the transistor count required for more straightforward gate techniques. For example, while the conversion of the function $f = \overline{AB} + \overline{C}$ to functional logic **(Fig. 4)** uses only six transistors, the gate implementation would require 10. Such a reduction in transistor count has a dramatic effect on chip size when we apply it to large, complex, logic functions.

Isolation elements, though, are needed in the implementation of some digital functions, notably master/slave flip-flop configurations. Master-to-slave isolation **(Fig. 5)** is provided by decoupling V_{DD} and V_{SS} from inverter element "A" by use of series p- and n-channel transistors. Transmission gates are utilized to provide data, clock isolation and transmission during appropriate portions of the operating cycles.

The transmission gate is a voltage-controlled coupling device; p- and n-channel transistors are placed in a parallel configuration **(Fig. 6).** Either parallel transistor, by itself, varies widely in impedance as its source swings through its signal range, altering the gate-to-source bias. This parallel combination results in a relatively flat characteristic over the entire V_{DD} to V_{SS} input swing.

Anchor those floating inputs

If CMOS inputs are not connected, drift may occur due to the leakage characteristics of the input structure. Under dynamic system conditions, coupled noise can propagate through floating inputs, leading to increased power dissipation and/or apparent circuit malfunction. For these reasons all inputs should be connected to a gate output or voltage supply. The level to which inputs are tied cannot be arbitrarily selected, because gate operation from other inputs must not be disabled. Unused NOR gate inputs must be tied to V_{SS}; NAND inputs, to V_{DD}.

Forward biasing inputs or outputs

Under normal conditions, switching junctions on the CMOS chip operate under reverse bias. There are, however, possible situations under which for-

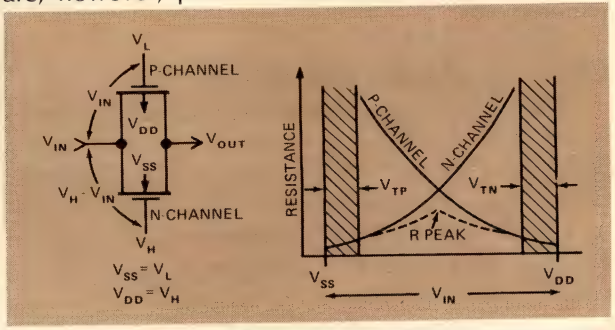


Fig. 6—Resistance between the input and output of a transmission gate is a function of the input voltage and the gate-to-substrate voltage. The effective resistance between the input and the output is the parallel combination of the resistance of the p-channel and n-channel devices.

ward biasing could occur. The consequences vary depending on the specific technology and degree of forward bias.

If we drive CMOS inputs or outputs by a low-impedance source, current flow could be sufficient to damage either the chip or wire bonding. Lower bias levels, on the other hand, can activate lateral or vertical parasitic bipolar transistors. The most serious such effect is an npn/pnp parasitic combination that latches up in SCR fashion and shorts V_{DD} to V_{SS} **(Fig. 7).** This ultimately destroys the chip.

A general rule can be established when using CMOS: Avoid a forward bias condition sufficient to supply drive to parasitics by keeping all pins within the range $V_{SS} - 0.3 \le V_{Pin} \le V_{DD} + 0.3$. When a forward bias condition is unavoidable, a resistor can then be used to limit current to a level not sufficient for activation of parasitic transistors. A future article will present a more detailed discussion of this forward bias phenomenon.

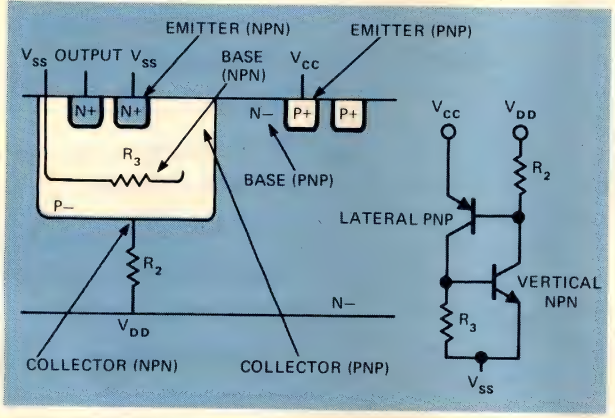


Fig. 7—This SCR configuration, when properly biased, can latch up conducting current sufficient to damage a CMOS device. The latch mode can be triggered by forward biasing either an npn or pnp base-emitter junction in the above configuration, both of which normally operate under reverse bias.

Switching characteristics, as well as dc drive capabilities, exhibit a negative temperature coefficient of 0.3%/°C due to degradation of the channel mobility with increasing temperature. These switching parameters normally are specified at 25°C and, therefore, must be derated by specific operating requirements.

Charging toward catastrophy

CMOS's high input impedance, however, is also responsible for what is its most serious handling problem—damage due to application of STATIC CHARGE across the device terminals. Application of such charge to a CMOS input usually results in a gate-to-drain or gate-to-source short, a catastrophic failure. This phenomenon is more common in low humidity climates, but can become serious in any assembly area employing commonly used environmental control methods. The failure mode is the rupture of the thin-gate oxide due to the high voltage built up on application of a static charge.

If we follow some simple handling procedures, we can minimize device losses in assembly environments. Briefly summarized, these rules recommend effective grounding of handling personnel and equipment, and the shunting of device leads during various phases of transport and assembly.

Minimizing power

DC power consumption is a function of leakage currents. Over the specified supply range, the total I_{DD} leakage is typically in the picoampere to nanoampere range. For circuits operating at moderate to high speeds, this component can normally be ignored in the determination of total power.

Most CMOS power, at high operating frequencies, is consumed in driving capacitance. **Fig. 8** shows the power supply current waveform for an inverter or gate circuit under a transient condition. The large positive current coinciding with the negative-going input transition is pulled from V_{DD} through p-channel device to charge C_L.

Capacitive load power for a given CMOS function can be determined from the equation $P = f \times C_L \times V^2_{DD}$, where f is the frequency at which the output is switching. This formula can be derived as follows:

The energy stored in the load capacitance when charged to V_{DD} is:

$$E = 1/2\ C_L\ V^2_{DD}$$

For a gate, this energy must be delivered to the load capacitance through the p-channel device as the output switches to V_{DD}, and removed as it switches to V_{SS}. Thus, the total energy required to charge and discharge the load capacitance during one cycle is:

$$E_{Total} = C_L\ V^2_{DD}$$

Power = Energy per unit time where time is the period of the operating frequency.

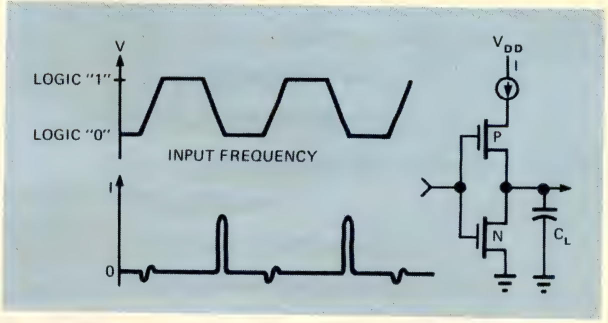


Fig. 8—The majority of power supply current flows through the p-channel transistor to charge C_L during the negative-going input transition. The current variation during the positive-going input transition has two components:

1. Momentary capacitive coupling through the overlap capacitance of a voltage greater than V_{DD} contributes a negative component.
2. Serial current flows through both p- and n-channels during the input transition while both transition transistors are thresholded.

$$T = \frac{1}{f} \qquad \text{Where } T = \text{Period}$$
$$f = \text{Frequency of Operation}$$

$$\text{Power} = \frac{E_{Total}}{T} = \frac{E_{Total}}{\frac{1}{f}} = fC_L V_{DD}^2$$

As we mentioned earlier, some current does flow serially through the complementary devices during that portion of the input transition when both p- and n-channel devices are ON. This condition becomes more prominent with higher values of $V_{DD} - V_{SS}$. Longer transition times at a gate input will extend the period during which the V_{DD} to V_{SS} series path is conducting, and increase total power consumption. However, this component of the total power is normally insignificant for most CMOS devices. Possible exceptions are inverting buffers. These devices have the widest range of linear operation and represent a substantially lower impedance between supplies when operating in the linear region.

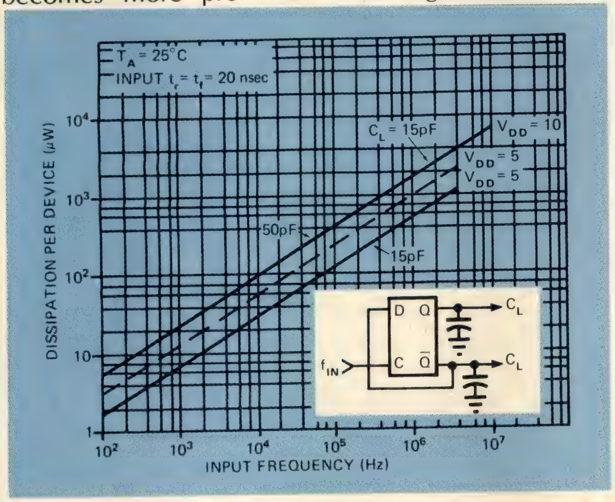


Fig. 9—To illustrate the $P = fC_L V_{DD}^2$ relationship, the average power dissipation vs. clock frequency is shown for ½ of an HD-4013 set up for the toggle mode. Both Q and $\bar{Q}$ are loaded with C_L.

Remember, also, that a capacitive load resembles a short circuit. Heavy capacitive loading, on the order of thousands of picofarads, can result in excessive package dissipation at high switching frequencies. Operating CMOS at the 15 pF or 50 pF loading, for which delays are normally specified, will keep the package well within safe dissipation limits. □

Author's biography

Ken Stephenson is digital applications manager at Harris Semiconductor. With Harris for one year, Ken presently is assigned to CMOS applications. He received his BSEE from University of Florida and lives in Melbourne, FL.

1953A Programmable Counter/Timer

One of Fluke's 'New Breed' of powerful LSI/MOS counters

$849

U.S. price F.O.B. Buffalo, N.Y.
Remote programming and other options extra.

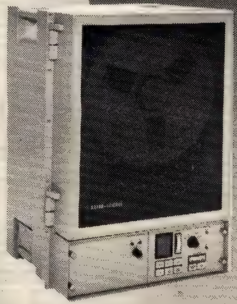
FLUKE®
COUNTER DIVISION

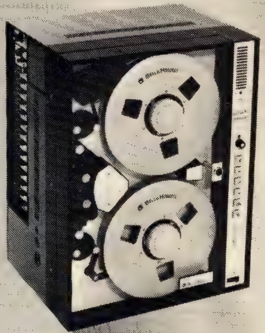
John Fluke Mfg. Co. Ltd.
Counter Division
P.O. Box 1094 Station D
Buffalo, N.Y. 14210
Phone (716) 842-0311 TWX 610-492-3214

For a demonstration Circle No. 18

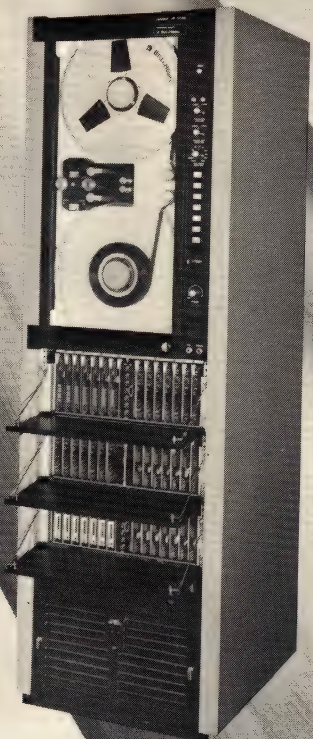
For more information Circle No. 44

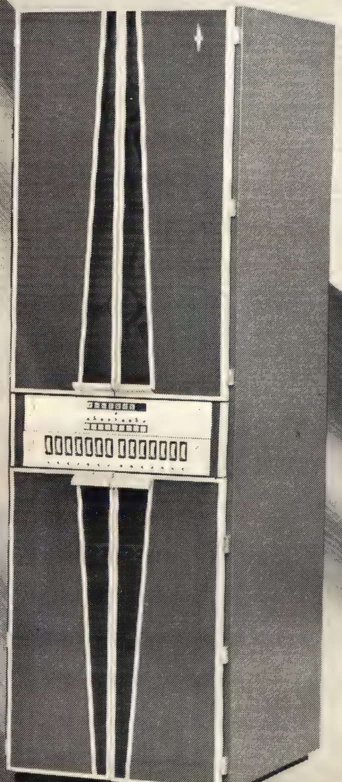
One for All and Four for One





Because magnetic tape recording needs differ, Bell & Howell has four precision laboratory-grade instruments to handle data acquisition and reduction requirements. • From the laboratory to remote locations, from airborne applications to submarine data collection, these Bell & Howell recorders meet the most stringent environmental and military standards. • Bell & Howell's M-14 Series meets Navy standards for use in ELINT (electromagnetic intelligence) activities. Compact, lightweight and reliable, these 14 or 28 track recorders are at home in the instrumentation laboratory or in nuclear submarines. • The CPR-4010, a 14-channel recorder/reproducer, has many of its big brothers' features. Expandable to 28 tracks, it is completely self-contained, portable and is one of the most cost-effective tape recorders available. • For performance and dependability, few recorders match the VR-3700B. Its performance specifications and characteristics are unmatched by any competing recorder. It can also record up to 80 million BPS over 28 tracks. • STARR, the State-of-the-Art Recorder/Reproducer, was designed to handle virtually every difficult data reduction task. Wide dynamic range, data integrity, spectral purity and ease of operation are major design considerations of STARR. • These, like all Bell & Howell recorders, are backed by nearly 30 years in the design and development of quality instrumentation. • For more information on how we can help you handle your recording requirements, contact William Zondler at (213) 796-9381 or circle the information retrieval number. • We have four good solutions to your magnetic tape recording problems.





CEC/INSTRUMENTS DIVISION

360 Sierra Madre Villa, Pasadena, California 91109

BELL & HOWELL

M-14 and STARR are trademarks of Bell & Howell Company

For more information, Circle No. 19

© Bell & Howell 1975

Designer's Guide to: EMI shielding, Part 1

Users and designers of electrically powered equipment must consider EMI implications and be ready to counteract problems.

John Severinsen, Metex Corp.

For many years, users and manufacturers of commercial electronic equipment could generally ignore EMI, which either emanated from their equipment or caused it to malfunction. Today, however, EMI is no longer the sole concern of engineers working on military or space systems.

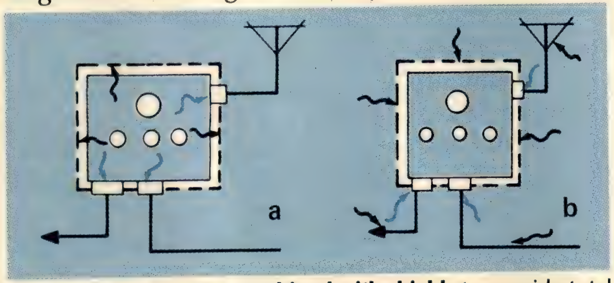


Fig. 1—Filters must be combined with shields to provide total EMI protection.

Some reasons for this new trend are:

- Stricter legislation. Section 302 of the Communication Act makes the manufacturer as well as the user responsible for electronic interference caused by equipment.
- Greater use of solid-state control devices such as SCR's. As well as being EMI sources, they are very responsive to interference. An SCR or UJT transistor is much more likely to become conductive because of a voltage spike than the old-fashioned relay it replaces.
- Increasing reliance of government, industry and the public on computers and peripheral equipment that is extremely susceptible.
- More critical dependency on electrical devices—pacemaker heart stimulator, self-service elevators, navaids for near zero-zero flying, etc.
- Increased "electronic pollution." The pollution from legitimate sources is bad enough, illegitimate interference makes a bad problem worse.

In its broadest definition EMI is "any electromagnetic energy that causes an undesirable response." In most cases, an EMI source causes a malfunction to occur in other electrical or electronic equipment. It is possible, however, that the source of EMI and the malfunction due to it can occur in the same equipment or system.

Keep it in, or keep it out?

There are three basic ways of controlling EMI:

- Redesign the source so that it produces less EMI.
- Redesign the malfunctioning equipment so that it is less likely to respond to EMI.
- Prevent the EMI energy from leaving the source or entering susceptible equipment.

Interference-causing energy can escape from the source (**Fig. 1a**) in two ways: conduction along wiring and cabling leaving the equipment (colored arrows), and direct radiation (black arrows).

When EMI filters are installed, conducted interference is contained. These devices conduct the desired currents (power in, data out, RF energy to antenna) but reject the undesirable currents. However, energy can still leave the source by direct radiation.

A shield, as shown in **Fig. 1a**, prevents the radiated EM energy from leaving the source. Thus both filtering and shielding are needed to contain EMI.

In a similar manner, **Fig. 1b** shows how filtering and shielding combine to exclude EMI from susceptible equipment. If only filtering is installed, interference could still enter by direct radiation; if only shielding is used, interference would be conducted by the wiring through the shield and into the equipment.

Any one that has ever made a shielded enclosure to contain EMI from an industrial RF heater, or similar device, will be very aware of this principle. He finds, sooner or later, that his shielded room is no better than the EMI filters through which he brings power into the enclosure.

EMI filters are available from several manufacturers that specialize in the design of filters for all kinds of conducted EMI problems. They are listed in standard industrial product directories. Shielding requirements are not so easily solved, however. Proper design requires some knowledge of the EM field, and what a shield really does.

Getting to know the enemy

Four electromagnetic field characteristics are important in shielding theory: frequency, wavelength, strength (or intensity) and impedance. Frequencies up to 20 GHz are commonly encountered in EMI work.

In **Fig. 3**, actual wavelengths for frequencies normally encountered in EMI work are shown by the curve marked 1λ. Since important differences in shielding occur when the shield is less than 1/100 wavelength from the source, or when shield discontinuities are more than 1/100 wavelength long, the second curve shows actual dimensions for 1/100λ.

Field strength or intensity is a measure of the power or "strength" of the field. Three units can be used to measure this characteristic:

Watts/square meter measures field strength in terms of its power or energy density; how much energy impinges on a given area. When measured directly, calorimetric techniques are used.

Volts/Meter measures the intensity of the electric portion of the EM field with a rod antenna.

Amperes/Meter is a measure of the intensity of the magnetic field portion of the EM field. Amperes/meter is measured by using a loop antenna.

The last two units are related to each other by the fourth EM field characteristic, impedance.

Impedance compares the magnetic field intensity, H, to electric field intensity, E. Specifically,

$$Z = \frac{E}{H}$$

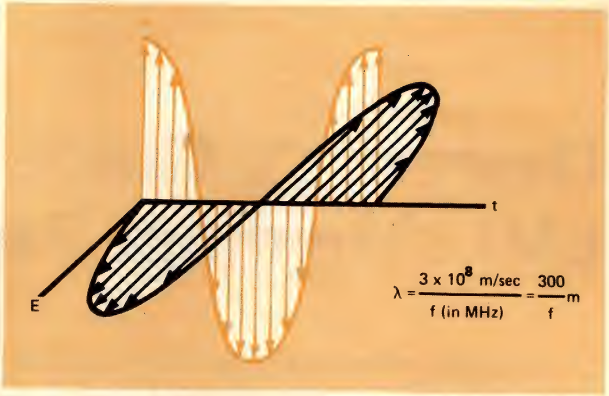

t
E
$\lambda = \frac{3 \times 10^8 \text{ m/sec}}{f \text{ (in MHz)}} = \frac{300}{f} \text{m}$

Fig. 2—Although it's only one component of the EM wave, the magnetic field presents the major shielding problem.

An EM field of "normal" characteristics has an impedance of 377Ω. This means that an EMI wave propagating freely through air, and far enough removed from its source (>1λ) and any other objects, will always have a fixed ratio between the electric field intensity and magnetic field intensity of 377Ω. If the E component is more intense than normal, the field is called an "electric field" or "high impedance field" and, conversely, a field with higher than normal H component is a "magnetic field" or "low impedance field."

How is shielding specified?

Simply stated, a shield reduces the EM field strength. It has no effect on the frequency or wavelength, and any changes in field impedance are not important to EMI control.

Shielding is measured and specified in terms of the reduction in field strength caused by the shield. Thus, when a shield is evaluated, two measurements are required: the field strength with and without the shield. The shielding achieved is the change in field strength, and is specified in decibels.

$$S(\text{dB}) = 20 \log \frac{E1}{E2} \text{ or } 20 \log \frac{H1}{H2} \text{ or } 10 \log \frac{P1}{P2}$$

where 1 and 2 refer to unshielded and shielded measurements, respectively.

Since the decibel is the universal measure for shielding, it is very important to clearly understand its meaning and to have a "feel" for its magnitude. A decibel compares two values; it is not a measure of one value. This is a basic concept that should be kept firmly in mind. In shielding, it measures the change in field strength due to a shield, not absolute field strength.

How much is enough?

Anyone that has made shielding measurements or has been closely associated with EMI work has acquired a natural "feel" for what 30 dB or 50 dB

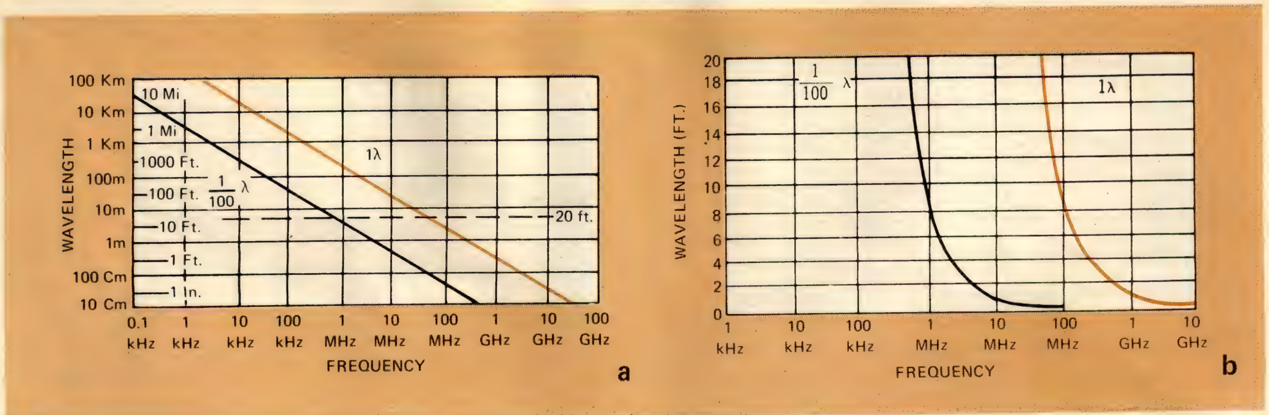


Fig. 3—Wavelengths for frequencies normally encountered in EMI work (**a**) are expanded in (**b**) to reflect dimensions typical for most shielding problems.

or even 100 dB means in a real-world, practical way. The following descriptions will impart some of this "feel" to those who have not yet acquired it. These descriptions are not, in any way, meant to be precise or all-inclusive. They are offered merely to help better understand the practical implication of the decibel.

0 to 10 dB is very little shielding. An enclosure that reduces an EM field by this amount hardly deserves to be called a shield. EMI, generally speaking, would not be eliminated.

10 to 30 dB would represent the minimum range for meaningful shielding. In mild cases, EMI would be eliminated, and shield design is very simple.

30 to 60 dB would be "average" shielding. It will solve all mild and some moderate EMI problems. Attention should be paid to good shield design.

60 to 90 dB is above average shielding, and is required to solve moderate to severe EMI problems. Shield design is of primary importance in equipment-housing design.

90 to 120 dB, generally speaking, is the maximum possible with the best shielding designs. Measurements require instrumentation specifically designed for this purpose, and in some cases measurement is beyond present state-of-the-art.

Over 120 dB is the limit of the state-of-the-art (with some specific exceptions) for instrumentation and shield design.

Shielding is a dual mechanism

A shield contains (or excludes) electromagnetic energy by reflecting or absorbing the energy. Whenever EM passes from one medium into another, a portion is reflected (like light at an air-to-water interface). Some energy does penetrate into the shield. Whenever EM energy passes through a conductive material, some of it is absorbed due to I^2R losses from induced currents. Therefore, the total shielding, S, possible from a material is the amount the field strength is reduced due to reflection R, plus the amount due to absorption A:

$$S = R + A$$

A more vigorous shielding theory would include reflections at the "exit" interface by giving this relation as $S = R + A + B$. But if $A > 10$ dB (which is almost always the case), B can be neglected.

The amount of EM energy absorbed by a shield depends on the impinging field's frequency, and the shielding material's thickness, conductivity and permeability.

Absorption is expressed, mathematically as:

$$A = 3.34T\sqrt{fG\mu}$$

where:

A = absorption, in decibels
T = thickness of shield, in mils
f = frequency, in megahertz
G = conductivity relative to copper
μ = relative magnetic permeability.

Fig. 4a shows the practical implications of the amount of shielding, due to absorption only, for 1/32-inch thick copper, aluminum and steel. This thickness is significant because mechanical considerations seldom allow the use of a thinner shield. Thus, above a few megahertz, any metal shield thick enough to be mechanically suitable will also be electrically suitable.

Shields that are thicker than 1/8-inch generally are mechanically unsuitable because of weight, difficulty in forming, etc. **Fig. 4b** clearly shows that additional absorption is gained by using 1/8-inch thick metals. However, copper or aluminum below 1 MHz may not be thick enough to provide enough absorption. To get the full picture, the amount of shielding due to reflection must be calculated.

Unfortunately, the reflection of EM energy by a shield is not as easy to compute or explain as absorption. Electromagnetic energy is reflected at

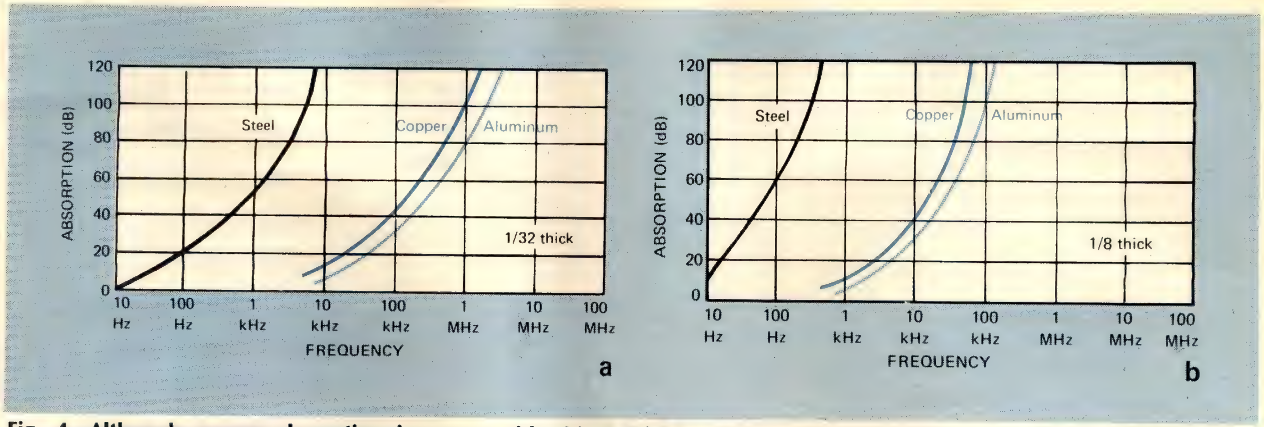


Fig. 4—Although energy absorption increases with shield thickness (b), mechanical suitability normally satisfies shielding requirements.

the surface of the shield, because the shield cannot accept all the energy that arrives at the interface. Impedance of the electromagnetic field, as it arrives at the shield, determines how much of it will be reflected, as given by the equation:

$$R = 20 \log \frac{Z_W}{4Z_s}$$

where:

R = reflection in decibels.

Z_W = impedance of the wave at the shield.

Z_s = impedance of shield, which in all practical shielding problems $\ll Z_W$.

Three basic electromagnetic field characteristics play an important part in coping with EMI.

1. All alternating electric fields gradually lose some of their intensity in generating a complementary magnetic field.

2. All alternating magnetic fields gradually lose some of their intensity in generating a complementary electric field.

3. At a distance of approximately one wavelength from either source, both fields will have the same "normal" impedance.

Stated mathematically:

$$Z_E = 60 \frac{\lambda}{r} \text{ or } Z_E = \frac{18(10)^3}{fr} \qquad \left(\frac{r}{\lambda} < 0.1\right)$$

$$Z_H = 2360 \frac{r}{\lambda} \text{ or } Z_H = 7.87\, fr \qquad \left(\frac{r}{\lambda} < 0.1\right)$$

$$Z_P = 377 \qquad \left(\frac{r}{\lambda} > 1\right)$$

where:

Z_E = impedance of electric wave.

Z_H = impedance of a magnetic wave.

Z_P = impedance of a plane wave.

r = distance in meters from source.

λ = wavelength.

f = frequency in megahertz.

How much difference source impedance can make in the reflection portion of shielding is borne out in **Fig. 5**. Shown is the reflection for EM fields, from electric and magnetic sources 12 inches from the shield, for the same three metals used to show absorption in **Fig. 4**.

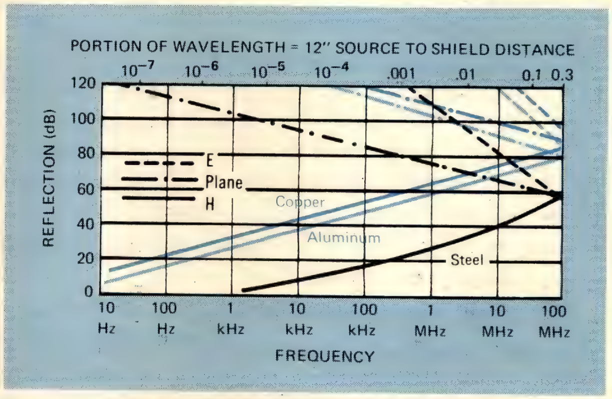


Fig. 5—Reflection capability vs. impedance is shown by difference in levels between high-impedance E and low-impedance H fields.

Reflection occurs at the air-to-metal interface. It is, therefore, unaffected by thickness provided the shield is at least a few mils thick. Reflection for plane-wave field is included for reference only since special antenna techniques would be required to generate a plane wave at the frequencies shown, only 12 inches from the source. (Beyond one or two wavelengths, EM waves are called "plane waves" because the relatively small portion of a spherical front that arrives at a shield will be flat or plane.) Note that the H fields and E fields converge to the plane-wave line as distance approaches one wavelength (see scale at top of curve).

This curve also clearly shows why low-frequency E field shielding is seldom a problem; the reflection is much, much more than would ever be needed. Not so for the H field; its reflection becomes less at lower frequencies.

Absorption plus reflection

Fig. 6 shows total shielding of magnetic fields, with a source-to-shield distance of 12 inches for copper, aluminum and iron; both 1/32-inch and

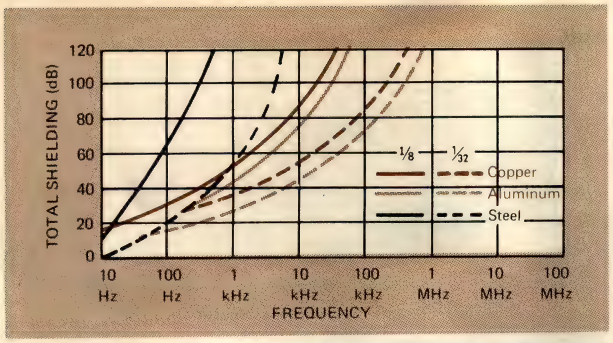


Fig. 6—While total shielding of magnetic field decreases with frequency, electric field shielding is too high to be shown on graph.

1/8-inch thick. Total shielding for all plane wave and electric fields would be more than 120 dB and couldn't even be shown on this curve.

For low-frequency magnetic field shielding, reflection is so small, and not affected by shield thickness that total shielding can be increased only by increasing the EM energy absorption.

Thus, low-frequency magnetic shielding is increased by:

- increasing T, the shield thickness.
- increasing G, the shield conductivity.
- increasing μ, the shield permeability.

Real-world complications

Solid, continuous shields are seldom used in actual applications. Practical shields have discontinuities at covers, doors, panels, ventilating openings and panel hardware. Experience shows that these cracks and openings are often very leaky. In fact, data shows that all EMI leakage above 1 MHz is due to discontinuities.

Leakage of EM energy from a discontinuity depends mainly on the maximum length of the opening, and the impedance and wavelength of the energy wave.

An EM field (**Fig. 7a**) impinging on the shield will induce currents. When there is a break in the shield, the currents can't flow normally, and a voltage will develop. This voltage pattern, E_i, develops on the inside surface. However since the shield is a good conductor, a voltage E_o will also appear on the outside. The voltage is similar to one that would appear on a short piece of wire acting as an antenna. The slot actually becomes similar to an antenna, radiating EM energy caused by currents induced by the EM field on the inside.

Length, rather than width, of the opening is important because the voltage will be highest wherever the "detour" for the currents is longest. This peak point is at the center of the slot, and voltage increases as the length of the slot increases. The width has almost no effect on "detour" length, and, as a consequence, has little effect on the voltage (**Fig. 7b**).

Current levels induced are a function of wave impedance. A low-impedance wave will induce high currents, resulting in higher voltages. High-impedance waves will, of course, produce inverse results.

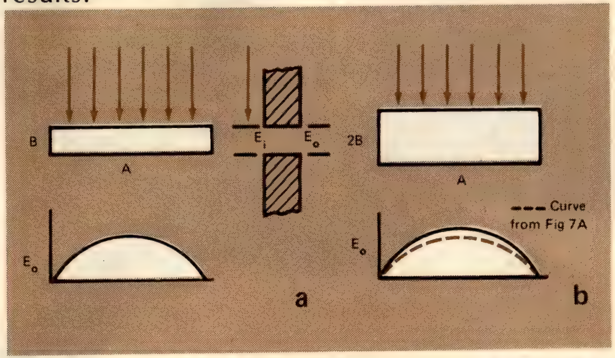


Fig. 7—Gap length, rather than width, is the crucial dimension in shield discontinuity leakage levels.

The degree of radiation from the "slot antenna" is a function of wavelength. If the slot happens to be a 1/4 wavelength or longer, it will be a very efficient radiator. On the other hand, slot lengths of less than 1/100 wavelength will be rather inefficient radiators. In essence, discontinuities of a few inches long, even if very narrow, can severely reduce the shielding capability of an enclosure above 100 MHz.

It's not a hopeless cause

Shield discontinuities are unavoidable, but help is available. By effectively shorting out the gap, EMI gaskets reduce the gap voltage and EM leakage. Gasket design is an art unto itself, and would require more coverage than the paragraph or two available here. Subsequent installments in this series will be devoted to an in-depth discussion of EMI gasket theory. ☐

Author's biography

John Severinsen is the Manager of Electronic Products at Metex Corp. in Edison, NJ and is responsible for the development and marketing of suppression materials and systems. A graduate of the University of Copenhagen with a BSME degree, he also attended secondary school in Denmark. During 16 years of experience, John has worked as a consultant on the design and production of electro-mechanical systems and equipment. An active participant in electronic industry professional affairs, he is a member of the Professional Engineering Society of Denmark and the IEEE.

1975

Caravan

The EDN Eighth Annual Mobile Trade Show will be on the road in January-March 1975.

This unique "Electronic Components Show" will exhibit products and capabilities of these participating companies:

AVX CERAMICS, Division of Avx Corporation
BURNDY CORPORATION
C & K COMPONENTS INC.
C. P. CLARE & COMPANY
DATEL SYSTEMS, INC.
GARRY MANUFACTURING COMPANY
GRAYHILL, INC.
T-BAR INCORPORATED, SWITCHING COMPONENTS DIVISION
WOVEN ELECTRONICS

EDN / 221 Columbus Ave. / Boston, Mass. 02116

We may be visiting your city—or perhaps your own plant site. Watch for the detailed tour schedule in our next issue.

1975 EDN ELECTRONIC COMPONENT — MOBILE TRADE SHOW TOUR ITINERARY — January 27, 1975 through April 2, 1975

DATE	TIME	SITE
1/17 A.M.	Monday 9-11:30	McDONNELL DOUGLAS, Lambert Street, St. Louis Airport, St. Louis, Missouri—Enter Brown Road, Gate #32. Van park near Building #33—Others use nearby visitors parking.
1/27 P.M.	Monday 2-4:30	McDONNELL DOUGLAS, Brown Road, St. Louis, Missouri Enter Gate #107, Brown Road. Van park at rear of Building #107—Others use nearby visitors parking.
1/28 A.M.	Tuesday 9-12:00	*EMERSON ELECTRIC, 8100 West Florissant, St. Louis, Missouri
1/29 A.M.	Wednesday 9-11:30	*WESTERN ELECTRIC, 777 North Blue Parkway, Lee's Summit, Missouri—Enter Truck Gate, Chipman Road. Van park at Receiving Dock Driveway—Others use visitors parking.
1/29 P.M.	Wednesday 2-4:30	*BENDIX CORPORATION, 2100 East Bannister Road, Kansas City, Missouri—Van park at Purchasing Building—Others use visitors lot.
1/30 A.M.	Thursday 9-12:00	*NATIONAL CASH REGISTER, 3817 North Rock Road, Wichita, Kansas—Van park in West parking lot—Others park near van.
1/31 A.M.	Friday 9-12:00	HONEYWELL INFO SYSTEMS, 4000 N.W. 39th Expressway, Oklahoma City, Oklahoma—Van park at Building #1 Others use visitors lot.
2/3 A.M.	Monday 9-11:30	*RECOGNITION EQUIPMENT, 2701 East Grauwler Road, Irving, Texas—Van park near Employee Entrance adjacent to Employee Parking Lot—Others park near van.
2/3 P.M.	Monday 2-4:30	E-SYSTEMS, 9314 West Jefferson, Grand Prairie, Texas—Van park at Building #198 Visitors Lot—Others park near van.
2/4 A.M.	Tuesday 9-11:30	&COLLINS RADIO, 1200 North Alma Road, Richardson, Texas
2/4 P.M.	Tuesday 2-4:30	*E-SYSTEMS, 1200 Jupiter Road, Garland, Texas—Van park adjacent to walkway and curb at south end of Building #551 Others use visitors lot #551.
2/5 A.M.	Wednesday 9-12:00	*TEXAS INSTRUMENTS, 135000 North Central Expressway, Dallas, Texas
2/6 A.M.	Thursday 9-11:30	TEXAS INSTRUMENTS, 12203 S.W. Freeway, Stafford, Texas Van park at DSD Building—Others park opposite side of street at Front Lobby.
2/6 P.M.	Thursday 2-4:30	SCHLUMBERGER TECHNOLOGY, 5000 Gulf Freeway, Houston, Texas—Van park at East Engineering & Cafeteria—Others park at East Employment Guard Gate.
2/7 P.M.	Friday 2-4:30	*DATA POINT, 9725 Data Drive, San Antonio, Texas—Van park in Southwest Parking Lot, outside Purchasing Lobby Others park near van.
2/10 A.M.	Monday 9-11:30	*IBM CORPORATION, 11400 F.M. Road 1325, Austin, Texas Van park in Visitors Lot in front of Main Gate—Others use north end of Visitors Lot.
2/10 P.M.	Monday 2-4:30	&TRACOR INC., 6500 Tracor Land, Austin, Texas
2/11 A.M.	Tuesday 9-12:00	&TEXAS INSTRUMENTS, 12501 Research, Austin, Texas
2/12	Wednesday	DRIVE DAY
2/13 A.M.-P.M.	Thursday 8-3:00	*MOTOROLA, INC., 8201 East McDowell Road, Scottsdale, Arizona—Van park at Receiving Security Guard Station Others park near van.
2/14 A.M.	Friday 9:30-12:00	*SPERRY FLIGHT SYSTEMS, 21111 North 19th Avenue, Phoenix, Arizona—Guard at South Gate will direct for parking.
2/14 P.M.	Friday 2-4:30	&HONEYWELL INFO SYSTEMS, 13430 North Black Canyon Highway, Phoenix, Arizona
2/17 A.M.	Monday 9-11:30	&GENERAL DYNAMICS, 3302 Pacific Highway, San Diego, Calif.
2/17 P.M.	Monday 2-4:30	&GENERAL DYNAMICS, 5001 Kearney Mesa, San Diego, Calif.
2/18 A.M.	Tuesday 9-11:30	&TELEDYNE RYAN AERONAUTICS, 2701 Harbor Drive, San Diego, Calif.
2/18 P.M.	Tuesday 2-4:30	&NAVAL ELECTRONICS LAB, 271 Catalina Boulevard, San Diego, Calif.
2/19 A.M.	Wednesday 9-12:00	&BURROUGHS, 25725 Jeronimo Road, Mission Viejo, Calif. Van park in visitors lot in front of building—Others park near van.
2/20 A.M.	Thursday 9-11:30	*PHILCO FORD CORPORATION, Ford Road, Newport Beach, Calif. Van park at Environmental Test Building—Others use parking lot, West Gate.
2/20 P.M.	Thursday 2-4:30	&VARIAN DATA MACHINES, 2722 Michelson Drive, Irvine, California (To be confirmed)
2/21 A.M.	Friday 9-11:30	*NORTHRUP CORPORATION, 500 East Orangethorpe, Anaheim, California—Van park adjacent to Building Y-2—Others park near van.
2/21 P.M.	Friday 2-4:30	&ROCKWELL INTERNATIONAL, 3370 Miraloma Avenue, Anaheim, California—Van park in parking lot at 3rd and Coronado—Others park near the van.
2/24 A.M.	Monday 9-11:30	&GENERAL AUTOMATION, 1055 South East Street, Anaheim, California
2/24 P.M.	Monday 2-4:30	&BECKMAN INSTRUMENTS, 2400/2500 Harbor Road, Fullerton, California—Enter Lambert Road, Gate #1. Van Park at Building #1—Others in General Parking.
2/25 A.M.	Tuesday 9-11:30	*HUGHES AIRCRAFT, 1901 West Malvern Avenue, Fullerton, California—Van park between Building #601 & #604 Others park in visitors lot, Gate #6.
2/25 P.M.	Tuesday 2-4:30	XEROX CORPORATION, 600 East Bonita Avenue, Pomona, Calif. Guard at 600 East Bonita will direct van—Others park in parking lot.
2/26 A.M.	Wednesday 9-11:30	&GENERAL DYNAMICS, 1675 West Mission Boulevard, Pomona, California
2/26 P.M.	Wednesday 2-4:30	HOFFMAN ELECTRONICS, 4323 North Arden Drive, El Monte, California—Van park in south parking lot near door #19 Others park in vendors lot.
2/27 A.M.	Thursday 9-11:30	XEROX CORPORATION, 300 North Halstead, Pasadena, Calif. Van enter at 300 North Halstead, Vern Smith will direct for parking—Others same directions.
2/27 P.M.	Thursday 2-4:30	&BELL & HOWELL, 300 Sierra Madre, Pasadena, California
2/28 A.M.	Friday 9-11:30	*BURROUGHS CORPORATION, 460 Sierra Madre, Pasadena, California—Van park inside fence between Main Gate and Credit Union—Others use visitors lot.
2/28 P.M.	Friday 2-4:30	&LITTON SYSTEMS, 5500 Canoga Avenue, Woodland Hills, California
3/3 A.M.	Monday 9-11:30	&SINGER COMPANY, 2350 Washington, San Leandro, California
3/3 P.M.	Monday 2-4:30	AMPEX CORPORATION, 401 Broadway, Redwood City, California—Van park in parking lot at rear of Corporation Headquarters—Others park near van.
3/4 A.M.	Tuesday 9-11:30	&HEWLETT PACKARD, 1501 Page Mill Road, Palo Alto, Calif.
3/4 P.M.	Tuesday 2-4:30	PHILCO FORD, 3939 Fabian Way, Palo Alto, California—Van park at Building #1, North side parking area—Others park near van.
3/5 A.M.	Wednesday 9-11:30	VIDAR CORPORATION, 77 Ortega Avenue, Mountainview, California—Van park at southeast corner of parking lot Others park near van.
3/5 P.M.	Wednesday 2-4:30	&INFORMATION STORAGE SYSTEMS, 10435 North Tantau, Cupertino, California
3/6 A.M.	Thursday 9-11:30	*HEWLETT PACKARD, 11000 Wolfe Road, Cupertino, California Van park at North side of parking lot, corner of Homestead and Wolfe Road, rope area—Others park near van.
3/6 P.M.	Thursday 2-4:30	*HEWLETT PACKARD, 5301 Stevens Creek Boulevard, Santa Clara, California—Van park at Building #51, west side—Others use visitors lot.
3/7 A.M.	Friday 9-11:30	MEMOREX, Central and San Tomas, Santa Clara, California Van park in general parking area, roped area—Others park near van.
3/7 P.M.	Friday 2-4:30	&ITEK CORPORATION, 645 Almandor, Sunnyvale, California (To be confirmed)
3/10 A.M.	Monday 9-11:30	BURROUGHS CORPORATION, 6300 Hollister Avenue, Goleta, California—Van park at rear of north parking lot—Others use vendors parking lot.
3/10 P.M.	Monday 2-4:30	TELEDYNE SYSTEMS CORPORATION, 19601 Nordhoff, Northridge, California—Van park in parking lot at north side of building—Others park near van.
3/11 A.M.	Tuesday 9-11:30	SINGER COMPANY, 833 Sonora Avenue, Glendale, California Van park in visitors lot at Main Administration & Employment area—Others park near van.
3/11 P.M.	Tuesday 2-4:30	&CONTROL DATA CORPORATION, 2815 West El Segundo Boulevard, Hawthorne, California INVITEE-TRW-DATA SYSTEMS NORTHRUP AIRCRAFT CORPORATION, 2301 West 120th, Hawthorne, California (To be confirmed)
3/12 P.M.	Wednesday 2-4:30	&XEROX DATA SYSTEMS, 701 South Aviation Boulevard, Segundo, California
3/13 A.M.-P.M.	Thursday 9-3:00	&HUGHES AIRCRAFT COMPANY, Centinella & Teale, Culver City, California
3/14 A.M.	Friday 9-11:30	ITT GILFILLAN, 2821 Orion, Van Nuys, California—Van park in roped area of parking lot—Others park near van.
3/14 P.M.	Friday 2-4:30	*RCA CORPORATION, 8500 Balboa Boulevard, Van Nuys Calif. Van park in #306 parking lot—Others park near van.
3/17	Monday	DRIVE DAY
3/18 A.M.	Tuesday 9-11:30	HEWLETT PACKARD, 815—14th S.W., Loveland, Colorado—Van park at North side of Building #1A— Others in adjacent parking lot.
3/18 P.M.	Tuesday 2-4:30	*IBM CORPORATION, 6300 Diagonal Highway, Boulder, Colorado Van park in lot West of Building #021—Others park near van.
3/19 A.M.	Wednesday 9-11:30	STORAGE TECHNOLOGY, 2270 South 88th, Louisville, Colorado Van park North of entrance to Building #2—Others use parking lot.
3/19 P.M.	Wednesday 2-4:30	HONEYWELL, 4800 East Dry Creek Road, Littleton, Colorado Van park at East side of Building near employee entrance Others use visitors parking lot.
3/20 A.M.	Thursday 9-12:00	&MARTIN MARIETTA, 12250 South Highway 75, Littleton, Colorado—Van park in roped area near Engineering—Others park near van.
3/21	Friday	DRIVE DAY
3/24 A.M.	Monday 9-12:00	COLLINS RADIO, 5225 'C' Avenue N.E., Cedar Rapids, Iowa Van park at north of Building #108—Others park near van.
3/25 A.M.-P.M.	Tuesday 10:30-2:00	*IBM CORPORATION, 3605 Highway 52 North, Rochester, Minnesota—Van park on right side of circle and flag pole at entrance—Others use visitors lot.
3/26 A.M.	Wednesday 9-11:30	&HONEYWELL, AEROSPACE DIVISION, 2600 Ridgeway Road, Minneapolis, Minnesota INVITEE: HONEYWELL, 600 2nd St. North, Hopkins, Minn.
3/26 P.M.	Wednesday 2-4:30	*SPERRY UNIVAC, 2276 Highcrest Drive, St. Paul, Minnesota Van park at North end of Building #1—Security will direct others.
3/27 A.M.	Thursday 9-11:30	&3M CORPORATION, 2501 Hudson Road, St. Paul, Minnesota
3/27 P.M.	Thursday 2-4:30	CONTROL DATA CORPORATION, 4201 North Lexington Avenue, St. Paul, Minnesota—Van park at south side of building—Others park near van.
3/28	Friday	DRIVE DAY
3/31 A.M.	Monday 9-11:30	&WESTERN ELECTRIC COMPANY, 4513 Western Avenue, Lisle, Illinois
3/31 P.M.	Monday 2-4:30	&MOTOROLA COMMUNICATIONS, 1301 Algonquin, Schaumburg, Illinois
4/1 A.M.	Tuesday 9-11:30	&QUASAR, 9401 West Grand Avenue, Franklin Park, Illinois
4/1 P.M.	Tuesday 2-4:30	*TELETYPE CORPORATION, 5555 West Touhy, Skokie, Illinois Van enter Gate #7 (Carpenter Road), Guard will direct—Others enter Gate #6 (Carpenter Road) park in R & D visitor parking.

*Indicates NO VISITORS ALLOWED—Van and Exhibitor Personnel Only. &Indicates the Plant has not replied on the visitor question. An absence of any markings before the Plant name indicates the Plant *is* open to visitors.

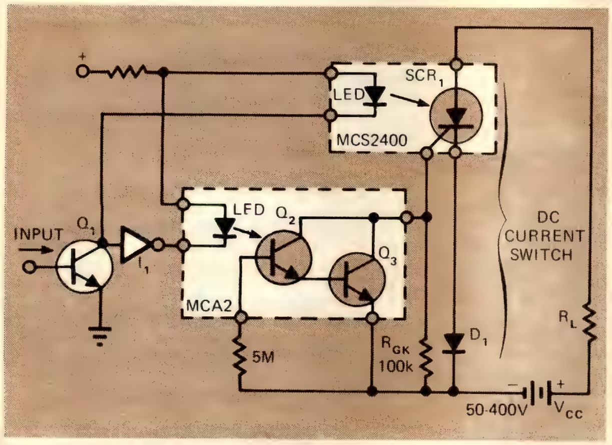
EDN DESIGN AWARDS

Opto-isolators switch high-voltage dc current

G. C. Riddle
Monsanto Corp., Palo Alto, CA

Because of the relatively low values of BV_{CEO} available in standard transistor opto-isolators, it is difficult to fashion a simple isolator circuit for switching high-voltage dc. However optically isolated photo-SCR's capable of blocking to 600V are available, so why not use them to do the job? The only problem is turning OFF the SCR. The following scheme uses the gate terminal.

Turn-OFF is accomplished when transistor Q_3 shunts the load current through the gate, thus bypassing the gate-cathode junction within the SCR. This interrupts the regenerative feedback path necessary to maintain the SCR in the latching state. A low-voltage transistor will accomplish this current bypassing provided it can conduct the full load current in saturation for as long as it takes the SCR to turn OFF, typically 5-10 μsec.



This basic dc switching circuit can be expanded to provide current reversing. However, this would require four identical circuits with the SCR's connected in a bridge network.

Both the SCR switch and transistor clamp are energized by light from an infrared LED. The MCS2400 has a minimum blocking voltage of 400V. Installation of diode D_1 provides an additional offset voltage that permits the gate circuit to be clamped by the Darlington. Resistor R_{GK} provides thermal stability at high temperature. The MCS2 photo-Darlington can conduct current to several hundred mA in saturation with a V_{CE} of <1V.

This circuit can be operated by pulsing the appropriate LED's to turn the SCR ON or OFF, and is stable in either state without a sustained signal. The dc current switch is held in either the ON or OFF state by the control circuit. Without an input signal, the collector of transistor Q_1 is logic HIGH, and the output of inverter I_1 is logic LOW. The inverter thus maintains current through the LED to the MCA2. This keeps the SCR clamped, while the LED to the MCS2400 is also OFF.

When an input signal pulls transistor Q_1 to saturation, a logic LOW, the LED to the MCS2400 is energized. Simultaneously, the inverter output goes to logic HIGH, turning OFF the MCA2. Therefore, the SCR will trigger ON and latch. □

To Vote For This Circuit
Circle No. 150

X-Y oscilloscope displays hysteresis loop of any core

David A. Zinder
Motorola Semiconductor, Phoenix, AZ

The hysteresis or B-H loop of a magnetic material is one of the most important considerations for the designer of large signal electronic-magnetic circuitry. A graph usually is plotted with an x-y recorder for the dc case; for the more common ac frequencies, a sampled-data system is used in conjunction with an x-y recorder. I will describe a circuit that allows display of a hysteresis loop on a calibrated x-y oscilloscope by use of an inexpensive integrated-circuit op amp.

The vertical axis of a hysteresis loop graph is the magnetic flux intensity, B, measured in magnetic lines of force/unit area (gauss). The horizontal axis of the curve is the magneto-motive force or magnetic field intensity, H, measured in ampere turns/unit of the magnetic path length (oersteds).

The relationship between electro-magnetic qualities can easily be derived as:

$$B = \frac{10^8}{NA}\int e\,dt$$

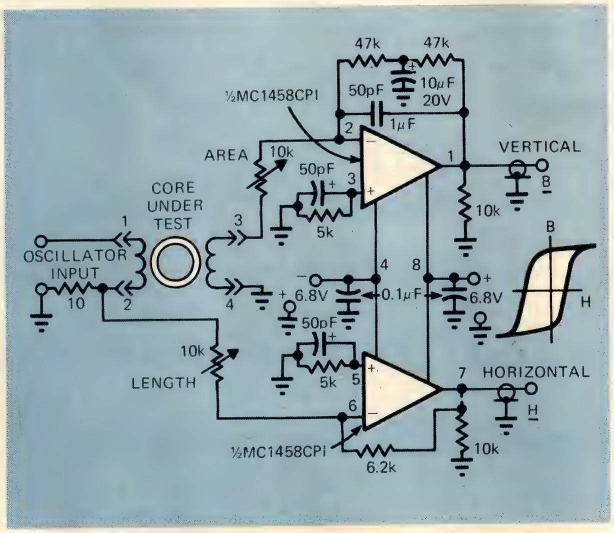
where e is the induced voltage across the coil; N, the number of turns in the coil; A, the effective core area; t, the time in seconds; and B, the flux intensity in gauss.

Thus, by selecting the RC product of an integrating amplifier circuit to match the constant $-NA/10^8$, the output voltage will be precisely the value of B. In a practical system, a scaling factor of 10^3 is introduced to make the output voltage of the amplifier large enough to drive the vertical scope sweep. Generally, two windings are placed on the core to be tested, with the amplifier in the flux measuring system connected to the secondary. This eliminates any error caused by IR drop in the primary.

The excitation term can be defined as:

$$H = \frac{NI}{d}$$

where N is the number of turns in the coil; I, the coil current in amperes; d, the magnetic path length in centimeters; and H, the field intensity in oersteds. A simple amplifier circuit suffices to provide the necessary amplification and scaling factor.



The most difficult design consideration in building this tester is to provide a universal winding for testing any core. MC1458CPI dual op amp is inexpensive, yet has ample gain to allow both portions of circuit to work well.

In the "B" portion of the circuit (vertical output), the input resistor is a 10-turn precision potentiometer. Since the feedback capacitor is fixed at 1 μF, the input resistor equals 100× the core area in square centimeters so that the dial on the potentiometer reads from 0 to 10 cm². Then, with a 50 turn secondary coil, the output ratio is 2000 G/volt. (A similar scale can be designed for English units.) Reducing the number of turns on the coil proportionately increases this ratio. The "T" circuit of two resistors and one capacitor in parallel with the feedback provides dc stabilization of the operating point. The network from the noninverting input to ground provides impedance matching and ac grounding of that input.

The "H" portion of the circuit (horizontal output) is a standard controlled-gain circuit. The 6.2 kΩ feedback resistor (ideally 6.28k) provides an output of 1V/oersted with a 50 turn coil. The 10-turn input potentiometer is adjusted so that its resistance in thousands of ohms is equal to the magnetic path length in centimeters. Reducing the number of turns on the coil increases the output ratio (volts/oersted) proportionately. The noninverting input is connected identically to that of the "B" portion.

Although use of this instrument is straightforward, a few simple precautions should be observed. Try to use as many turns as will fit on the core in convenient numbers—1, 2, 5, 10, etc. The input to the circuit may be any audio oscillator which will provide the necessary excitation at the desired frequency. Use sufficient amplitude to drive the core well into saturation, although the exact amplitude is unimportant. Both supplies should be bypassed close to the IC to prevent high-frequency oscillations. And, above all, for quantitative measurements be sure that the core size potentiometers are set properly. ☐

To Vote For This Circuit
Circle No. 151

Extend precision rectifier action to very low signals

Jerald Graeme
Burr-Brown Research Corp., Tucson, AZ

Offset nulling is routinely used to reduce errors in op-amp circuits, but straightforward nulling can degrade rather than improve precision rectifier performance. By means of more judicious op-amp offset nulling, precision rectifier operation can be extended to signals as low as 0.2 mV instead of an otherwise 5-mV limitation.

For a basic precision rectifier, straightforward nulling of A_1 does not result in the appropriate zeroing. The diodes switch when the polarity of the feedback current reverses, and not necessarily when the input or output voltage is zero. Even when A_1's offset is zero, feedback current sources shift the switching point of the feedback

THE μP MICROPROCESSOR

Don't let technology pass you by! Keep up with the most significant breakthrough in design since the Integrated Circuit — or even the transistor. Microprocessors are going to change your future!

EDN's μP DESIGN SERIES is the one and only authoritative μP source material for designers. And it's now available in reprint form. Collected together are 14 EDN articles, in full color, totaling 112 pages.

As a double bonus, we've included in the package a condensed recap of EDN's comprehensive μP MARKET STUDY (selling for $400) plus a complete Microprocessor Directory. The directory presents, in impressive detail, the μP technology that's available now to solve your design problems.

At $6.95/copy, this is a genuine bargain. You can't afford to be without it.

Order your copy now. Check or money order must accompany order. Make checks payable to: EDN μP Reprints.

Call Roy Forsberg, (617) 536-7780, for quantity discounts.

• •

EDN Microprocessor Design Series

ORDER BLANK

Send to: **μP Reprints**
EDN Magazine
221 Columbus Ave.
Boston, MA 02116

Please send me ______copies of EDN's μP series

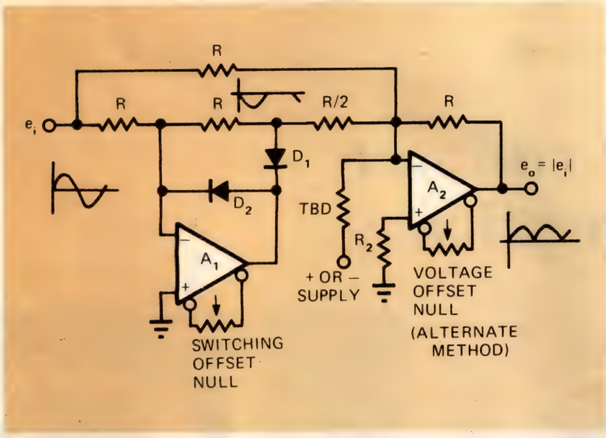
Enclosed is $______(Cost is $6.95 postpaid per complete 112 pg. set.)
Check or money order must accompany each order. No COD.
MA residents add 3% Sales Tax.

Send my series to: **Name** ____________________ **Title** ____________

Company ______________________________

Address ______________________________

City ______________ **State** __________ **ZIP Code** ________ diodes. This prevents rectification of low-level signals. No signal will be rectified unless it can overcome the feedback error current, and this typically requires 5 mV.



The TBD (to-be-determined) resistor can only be selected while the circuit is under test. A resistance decade box can be used to determine the value needed for voltage offset null. The closest fixed value resistor can then be hardwired in its place.

Precision rectification can be extended to a lower limit of about 200 µV by a special nulling procedure. First the input amplifier offset is adjusted to cause the diodes to switch when the input signal crosses zero. This should be done with a small, low-frequency test signal such as 10 mV at 10 Hz. While observing the anode of D_1, the offset control of A_1 is varied until the peak-to-peak swing of the signal observed is exactly one-half that of the input signal. Then the overall circuit offset is removed by selecting a resistor to connect from either positive or negative supply to the summing junction (inverting input) of A_2. Alternately, the offset may be removed using the offset control, but this will require iterative readjustment of the deadband and offset because the two interact. ☐

**Tŏ Vote For This Circuit
Circle No. 152**

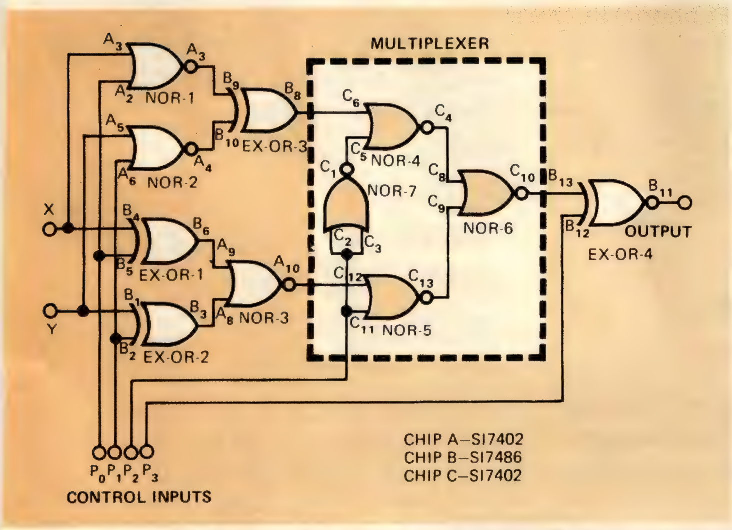
Programmable logic circuit has versatile outputs

S. Murugesan
Indian Sci. Satellite Proj., Bangalore, India

PROGRAMMING INPUT				OUTPUT
P_3	P_2	P_1	P_0	
0	0	0	0	$\overline{X + Y}$
0	0	0	1	$X \cdot \overline{Y}$
0	0	1	0	$\overline{X} \cdot Y$
0	0	1	1	$X \cdot Y$
0	1	0	0	$X \quad Y$
0	1	0	1	$\overline{Y}$
0	1	1	0	$\overline{X}$
0	1	1	1	1
1	0	0	0	$X + Y$
1	0	0	1	$\overline{X} + Y$
1	0	1	0	$X + \overline{Y}$
1	0	1	1	$\overline{X \cdot Y}$
1	1	0	0	$\overline{X \quad Y}$
1	1	0	1	Y
1	1	1	0	X
1	1	1	1	0

Using only three chips, this circuit outputs one of 16 possible functions of two Boolean variables, X and Y. Circuit operation is simple, and the table shows the output states for all the programming combinations of the inputs P_0, P_1, P_2 and P_3.

If we assume $P_0 = 0$, then NOR-1 outputs $\overline{X}$, and EX-OR-1 outputs X. If P_0=1, the output of NOR-1 changes to 0 and EX-OR-1 outputs $\overline{X}$. Similarly if P_1=0, NOR-2 outputs $\overline{Y}$ and EX-OR-2 outputs Y. P_1=1 condition gives rise to the output of NOR-2-0 and the output of EX-OR-2 = $\overline{Y}$. The outputs of NOR-1 and NOR-2 are EXCLUSIVE ORed by EX-OR-3. NOR-3 gets the inputs from EX-OR-1 and EX-OR-2. ☐



Depending upon the state of control input P_2, the multiplexer consisting of NOR-4, NOR-5, NOR-6 and NOR-7 selects either EX-OR-3 output or NOR-3 output and presents it to EX-OR-4. P_3=0 lets the output of NOR-6 go to the output of EX-OR-4, and P_3=1 inverts it.

**To Vote For This Circuit
Circle No. 153**

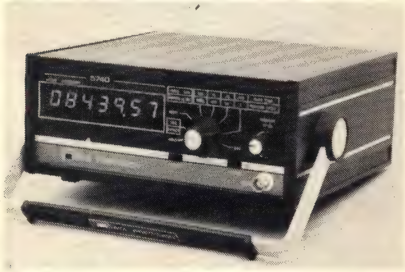
Vote now, by circling the appropriate number on the reader inquiry card.

Submit your own circuit, too. Mail entries to Design Award Program Editor, EDN, 221 Columbus Ave., Boston, MA 02116.

Full-function 100-MHz counter challenges the field on price

PROGRESS IN COUNTERS

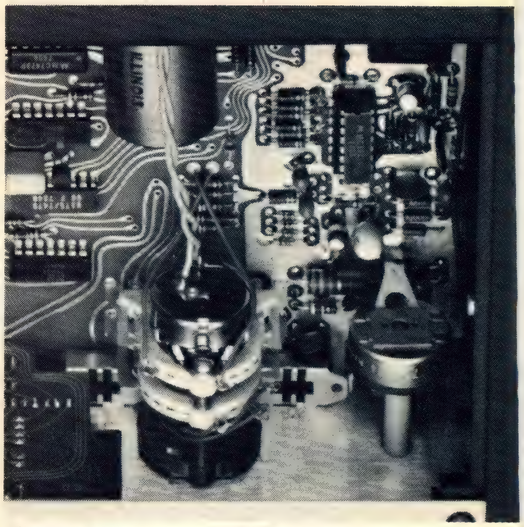
Carrying very respectable specs, the 7-digit 100-MHz Model 5740 digital counter/timer by Data Precision gives 5 functions for only $295. These are: frequency from 5 Hz to 100 MHz; single period (sinewave) from 1 µsec to 0.2 sec; period average with 1-nsec resolution to 99,999.99 µsec depending on the number of periods averaged (10, 100 or 1000); event counting (totalizing) from 0 to 10,000,000; and time interval (stop watch) measurement covering 0 to 99,999.99 sec (almost 28 hrs.).



100-MHz counter/timer with 10 mV rms sensitivity has input capability for both sinewaves and random pulses.

In addition to the full complement of functions and the surprisingly low price, this laboratory-quality instrument provides extreme simplicity of use. It handles a broad voltage spectrum and incorporates an adjustable trigger threshold. An input attenuator and post-coupling threshold adjustment enhance noise rejection, enlarge dynamic range and preserve full sensitivity (with generous hysteresis window) over a wide range of input waveforms, frequencies and duty cycles.

Display readability is excellent, thanks to the use of 0.43-in. LED digits. Other noteworthy features include a very low component count for good MTBF, 10 mV rms sensitivity, both sinewave and random-pulse input capability, automatic decimal placement, and an optional BCD output that provides counter-status timing signals as well as the reading and decimal-point data. The input circuit is compatible with most standard broadband scope probes, allowing an extension of the useful range.



Simple 2-wafer switching both reduces access problems in the Model 5740 and keeps the layout uncluttered.

Data Precision Corp., Audubon Rd., Wakefield, MA 01880. Phone (617)246-1600.

Circle No. 140

Portable cassette system gets people out of the data stream

PROGRESS IN INSTRUMENTATION

Everyone knows that the more people who handle data, the more errors there will be. Yet many companies employ terminal operators to collect data around the plant or country and then type it into the computer. Memodyne has cut such human data handling in half with the introduction of their completely portable "800 series" off-line, cassette recording systems.

Heart of the system is the Model 800 low-power, incremental transport. Providing ANSI/ECMA compatibility, this transport moves tape from stationary to stationary position in 1/1600th in. increments. It accomplishes this in 8 msec with the 5% accuracy required for flux change locations.

Portable means just that. Smaller than a breadbox, the systems use a single 5V dc source, drawing 60 mA when actually recording. Otherwise, drain is only 50 μA.

A typical system (Model 816) contains the transport, a write-step card and formatter card. Input is a parallel 7-bit ASCII character written in phase-encoded formats compatible with the ANSI/ECMA standards. Data is automatically blocked into 80-character lines with appropriate preambles, postambles, control chars., and gapping added. To record each char. requires 160 msec with 7 sec for the gapping mode.

Recording mediums are standard Philips cassettes which hold 2000 80-char. lines and fit in any terminal with a ANSI/ECMA cassette system.

The system is completely modular, so you can order only what you need. Model 816 is $745; Model 819, $870. Cases include power supply, front panel controls and I/O connector. Carrying case is $375, desk top case is $455 and rack mount case is $485. Availability is stock (up to 25).

Memodyne Corp., 369 Elliot St., Newton Upper Falls, MA 02164. Phone(617)527-6600.

Circle No. 141

Bringing home the data is the job of Memodyne's portable "800 series" off-line, cassette recording systems. They extend the computer terminal beyond its human operator to directly accept numbers of simple recorder stations via the link of the Philips cassette.

DPM is first of type to measure true rms value of any ac waveform

PROGRESS IN INSTRUMENTATION

Featuring performance formerly restricted to instruments costing four times as much, the Analog Devices' model AD2011 is the industry's first end-user product to combine panel meter package and price with full instrument capability. In fact, the $295 unit costs less than the extra cost option for true rms measurements offered with some DVM's.

The cost of making true rms measurements has decreased significantly. Many measurements can now be made more accurately by replacing iron-vane analog meters or average-reading meters with the $295 AD2011.

Tell me true (rms, that is)

Unlike most ac meters, which measure the rectified average, the AD2011 computes and displays the total effective dc heating value of its input. Each component of the input waveform is summed by the square root of the sum of the squares method. This assures measurement accuracy independent of the shape of the waveform, and fast (170 msec) response times. Total error for a sinewave input is ±0.1% reading ±0.1% FSR (full scale range) ±1 digit. For a 10% duty cycle pulse train, typical AD2011 error is ±0.9%, compared to −30% to −65% ±X% for a typical X% averaging meter.

AD2011 features four calibrated input ranges (1V, 10V, 100V and 1000V rms), a fully-floating opto-isolated input, three digits of 7-segment 0.55-inch Beckman displays, ac powering, BCD outputs and full control signals for interfacing to data logging or digital feedback control systems.

Analog Devices, Inc., Box 280, Norwood, MA 02062. Phone (617)329-4700. **Circle No. 142**

The whole truth about ACTIVE FILTERS

A reprint of EDN's series on active filters by Phil Geffe may not really be the last word on the subject—but it does contain a bonus—Part VI - "Elliptical Filters."

This series has received such excellent reader response that we have bound together the complete text, easy to file, ready for instant reference. Order your copy now. Check or money order **must** accompany order.

44 pages $3.50 postpaid

(cut along dotted line)

EDN

Active Filter Series
221 Columbus Ave.
Boston, MA 02116

Please send me ________ copies of Designers' Guide to Active Filters @$3.50 each. Payment enclosed. Make checks payable to EDN.

Quantity	0-9 $3.50
Rates	10-99 $2.95
	100 up $2.75

Name ________________

Company ________________

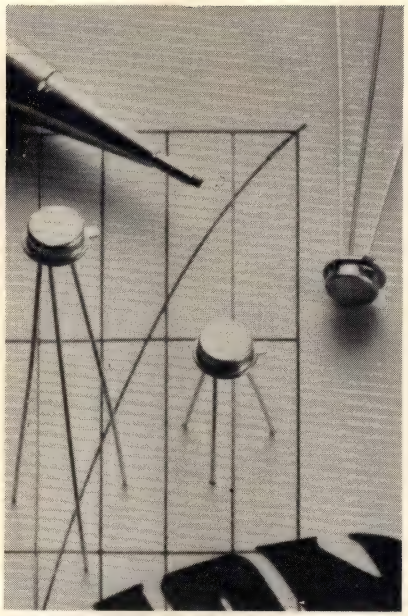
Address ________________

City ________________

State/ZIP ________________

MA residents add 3% Sales Tax

SEMICONDUCTORS



ONE-AMP RECTIFIERS FEATURE FAST RECOVERY TIME. Epitaxial ion-implantation is used in this device to reach max. recovery time of 10 nsec. Displaying this recovery time with voltage to 150V, these EPION™ rectifiers provide capacitance of 20 pF max. at 0V. Operating at −65 to 200°C max., the units are $1.98 (100). Solid State Devices Inc., 14830 Valley View Ave., La Mirada, CA 90638. Phone(213)921-9660. **Circle No. 170**

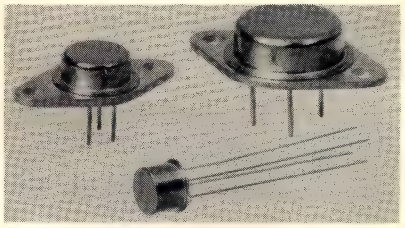
ULTRA STABLE ONE-SHOT USES CMOS. Operating from 3 to 18V, the N4528B dual monostable multi provides 2 independent resettable one-shot multivibrators. Quiescent power dissipation is <25 nW at 5V. All inputs are double-diode protected. Output pulse width is practically independent of power supply and temp. variation. Housed in a 16-pin DIP, the unit is $2.16 (100). Signetics, MOS Div., 811 E. Arques Ave., Sunnyvale, CA 94086. Phone(408)739-7700. **Circle No. 171**

BYTE-ORGANIZED CMOS RAM OPERATES STATICALLY. Three chip-enable inputs allow this 256-bit RAM to be expanded into a 2048-bit system without additional address decoding. Quiescent power dissipation is 10 μW/package @V_{DD} = 10V, T_A = +25°C typ. Access time, during a read operation, is typically 700 nsec. MCM14552, in a 24-pin DIP rated for commercial or military temperatures, $24 to $36 (25-99), according to temp. range and packaging. Motorola Semiconductor Products Inc., Box 20924, Phoenix, AZ 85036. Phone(602)244-3466. **Circle No. 172**

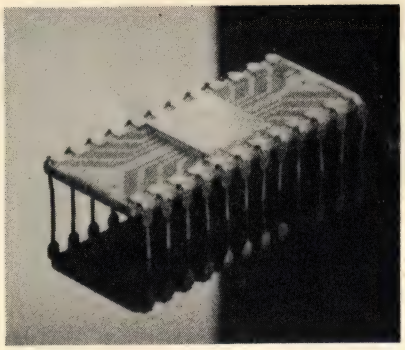
4k DYNAMIC RAM'S USE N-CHANNEL MOS. Featuring a guaranteed max. access time of 200 nsec and max. cycle time of 400 nsec, both units are TTL compatible. TMS4050 is offered in an 18-pin 300-mil wide DIP, while TMS4060 is housed in a 22-pin DIP. TMS4050 prices range from $26.73 to $24.30 and TMS4060 is $30.69 to $27.90 (100-999), plastic or ceramic. Texas Instruments Inc., Box 5012, Dallas, TX 75222. Phone(214)238-3741. **Circle No. 173**

256-BIT PROM'S ARE INTENDED FOR μP'S. The DM8577 has open-collector outputs, while the DM8578 has Tri-State^R outputs. Except for these output differences, the parts are identical. Both are field programmable and organized as 32 eight-bit words. The pROM's are available in both 16-pin cavity and molded DIP's. $6.70 (100) for molded. National Semiconductor Corp., 2900 Semiconductor Dr., Santa Clara, CA 95051. Phone(408)732-5000. **Circle No. 174**

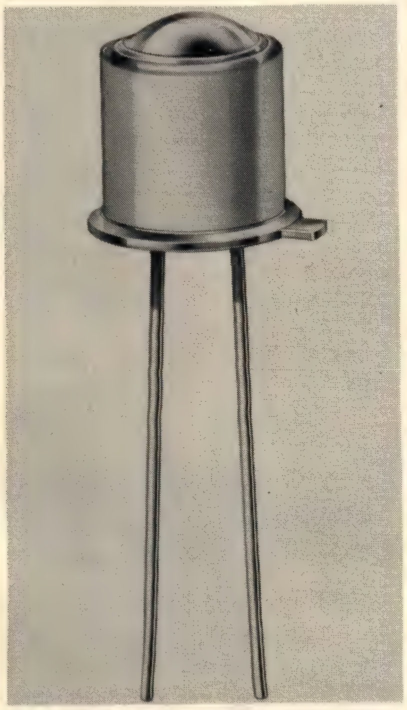
SOS COS/MOS OPERATES AT HIGHER SPEEDS. Having self-aligned silicon-on-sapphire to reduce parasitic capacitance, these IC's operate with low power dissipation. The technique used improves performance and increases yields, in addition to reducing the interelectrode capacitance. First to be offered is the TA6778 timing circuit, a ripple counter for high-speed operation in watches. It will be available in production quantities in the second half of 1975. RCA/Solid State Div., Box 3200, Somerville, NJ 08876. Phone(201)722-3200. **Circle No. 175**



HIGH VOLTAGE DARLINGTONS HANDLE 2 AND 5 AMPS. Designated U2T700 and U2T800, the monolithic units are available in hermetic TO-5, TO-66 and TO-3 packages. Rated at up to 300V, BV_{CEO}, they can handle dc currents to 5A or pulse currents to 10A. Gains are 2000 typ. at rated dc currents. $3.40 to $6 (100), depending on package and rating. Unitrode Corp., 580 Pleasant St., Watertown, MA 02172. Phone(617)926-0404. **Circle No. 176**



BIPOLAR ROM'S ARE PROGRAMMED BY USER. The two memories—2k-bit, 82S114 and 4k-bit, 82S115—have typ. access time of 35 nsec. Both devices are field-programmable and include buffered address lines, on-chip decoding and input current <100 μA. Both pROM's are Schottky-diode clamped and incorporate data output registers on their chips. $65(100). Signetics, 811 E. Arques Ave., Sunnyvale, CA 94086. Phone(408)739-7700. **INQUIRE DIRECT.**



INFRARED SOLID-STATE DIODE OPERATES AT 100 mA. Designed for use in high-speed sorting, intrusion alarms and data transmission, the SG1009A is supplied in a hermetically-sealed 2-lead TO-18 case. Typical power output at 940 nm is 7.5 mW@100 mA. The emitting source is a gallium-arsenide pellet assembled in conjunction with a glass lens. $3.50, small quantities. RCA Commercial Engineering, Harrison, NJ 07029. Phone(201)485-3900.

Circle No. 177

No Offense

Non-PCB (polychlorinated biphenyl) . . . non-toxic . . . non-polluting. That's new Sprague ECCOL® A-C Capacitors . . . developed for today's ecology-conscious world.

Equipment manufacturers using capacitors with polychlorinated biphenyl impregnants are finding that some nations have prohibited the import of products containing PCB.

ECCOL® capacitors have been designed to meet industry needs for PCB-free capacitors. They exhibit essentially identical electrical performance characteristics to those of long-used askarel capacitors. Their operating life and reliability are also equivalent. Even the size of ECCOL® Capacitors is similar to previous designs, except for a slight increase in case height.

Drawn-case ECCOL® Capacitors are available in a wide range of capacitance values from 1 to 55μF, with four voltage ratings from 300 to 660 VAC.

For complete technical data, write for Engineering Bulletin 4550 to:
Technical Literature Service
Sprague Electric Company
491 Marshall Street
North Adams, Mass. 01247

4SP-4113

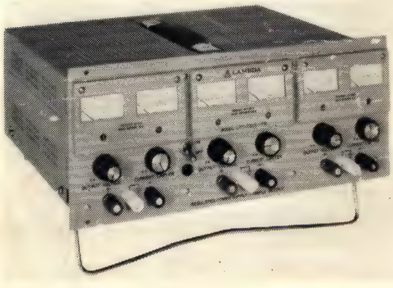
SPRAGUE®
THE MARK OF RELIABILITY

THE BROAD-LINE PRODUCER OF ELECTRONIC PARTS

For more information, Circle No. 20

SNAP-TOGETHER 5300 SYSTEM GETS 8-DIGIT MAINFRAME. Model 5300B, an alternate to HP's 6-digit Model 5300A, employs larger 7-segment readout digits. A TCXO that greatly exceeds FCC requirements is optionally available. New plugs-ons for the system include an 1100-MHz counter, a bus interface module and an improved D/A converter. Model 5300B, $460. TCXO option 001, $180. Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, CA 94304. Phone (415)493-1501. **Circle No. 179**

HETERODYNE COUNTER MAKES AUTOMATIC MEASUREMENTS TO 18 GHz. Using solid-state YIG and thin-film circuitry, the EIP 331 microwave counter provides fully automatic frequency measurements from 0.825 to 18 GHz. Its Autohet measurement technique provides unusual FM tolerance plus sensitivity. The center frequency of signals with up to 200 MHz FM deviation can be measured directly. Green LED's are used in the 7-digit display. $4000. EIP Inc., 3130 Alfred St., Santa Clara, CA 95050. Phone(408)244-7975. **Circle No. 180**

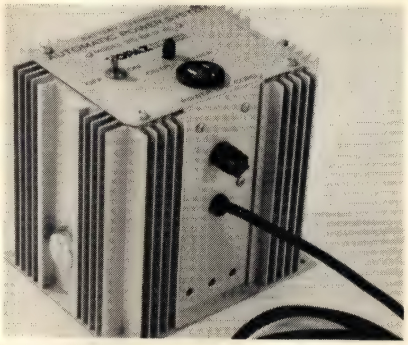


FULL .METERING DISTINGUISHES TRIPLE-OUTPUT LAB. SUPPLY. The LPT-7202-FM mounts in a 3/4 rack, but also is designed to sit on a bench or be carried around. Two 0 to 20V outputs and 1 at 0 to 7V deliver 1.5, 1.5 and 5A, respectively. Line and load regulation are 0.01% + 1 mV for line changes from 105 to 132V rms or 100% load change. $600, with 5-yr guarantee. Lambda Electronics Corp., 515 Broad Hollow Rd., Melville, NY 11746. Phone(516)694-4200.

Circle No. 181

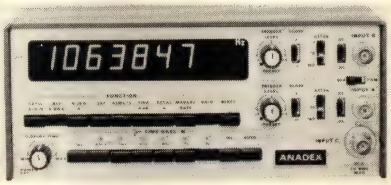
HANDHELD DIGITAL MULTIMETER ALSO MEASURES CAPACITANCE. Model 21 provides 4 ranges each for dcV, acV, Ω and capacitance. Resolution is 1 mV, 1 mV, 1Ω and 1 pF, respectively. The 3-1/2-digit (2000-count) display uses 0.27-in. LED's. Rechargeable nickel-cadmium batteries furnish power for portable operation, but an optional converter can be furnished for line operation. $269 complete with battery charger and belt carrying case. Data Technology Corp., 2700 S. Fairview, Santa Ana, CA. Phone(714)546-7160.

Circle No. 182



AUTOMATIC POWER BACKUP SWITCHES IN 1 LINE CYCLE. Model 315-12-60, rated at 300 VA, automatically senses primary power loss and transfers the load from the power line to a combination battery/inverter. The unit's battery charger employs a controlled charging rate to permit the use of lead-acid or gel-cell batteries. The charger, transfer switch and inverter are housed in a 7×7×5-1/2-in. case. $250. Topaz Electronics, 3855 Ruffin Rd., San Diego, CA 92123. Phone(714)279-0111.

Circle No. 183



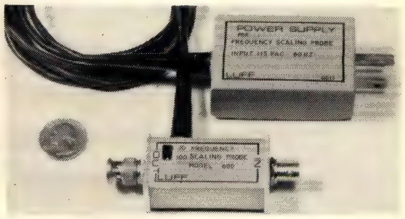
UNIVERSAL COUNTER-TIMER AUTORANGES ON FREQUENCY. Model CF-735 counts from dc to 80 MHz. It has pushbutton mode selection for frequency, frequency ratio, period, time interval and totalize. Sensitivity is 50 mV rms. Option C will provide capability of 600 MHz at 30 mV rms sensitivity. The 7-digit display uses 0.55-in. Sperry™ digits with units annunciator and overflow indication. Plug-in IC's are utilized throughout. $745 (option C, $280). Anadex Instruments Inc., 7833 Haskell Ave., Van Nuys, CA 91406. Phone(213)782-9527.

Circle No. 184

FM/DIRECT CASSETTE RECORDER RUNS FROM BATTERIES OR LINE. The 2-channel Model T5-2 instrumentation recorder uses cassette tapes and has both record and reproduce capability. FM record/reproduce frequency response is dc to 1000 Hz and direct record response is 100 to 10,000 Hz. Both ac and dc input coupling are provided, and signals in the range of 100 mV to 2V pk. may be recorded by proper range-control setting. Delivery, 6-8 wks. $2700. Dallas Instruments, Inc., 10205 Plano Rd., Dallas, TX 75238. Phone(214)341-2990. **Circle No. 185**

DATA LOGGER SCANS, DISPLAYS, LOGS AND ALARMS. Digitrend 200 does these for outputs from thermocouples, transducers, transmitters, strain gages or millivolt sources. The basic multipoint recorder contains an input panel, cold-junction compensation, solid-state or electromechanical scanning, A/D converter, digital display of scan point, digital display (in engineering units), printout, isolated BCD outputs and a built-in electronic timer. $2195. Doric Scientific Corp., 3883 Ruffin Rd., San Diego, CA 92123. Phone(714)565-4415.

Circle No. 186



FREQUENCY-SCALING PROBE EXTENDS COUNTING TO 600 MHz. Model 600 attaches directly to a counter and allows input frequencies to be divided by either 10 or 100. The probe's extremely sensitive input amplifier makes possible measurements at typically better than −30 dBm to 600 MHz. The scaler's dc power is supplied by a wall-plug assembly with a 6-ft. interconnecting cord. $325. Luff Research Assoc., Box 449, Jackson Heights, NY 11372. Phone (212)429-5900.

Circle No. 187

PROM SCIENTIFIC CALCULATOR GIVES USER FLEXIBILITY. The Model PC-1002 calculator is a scientific model with 4 extra-function keys and a receptacle for accommodating a plug-in pROM module. The module incorporates a custom-designed chip whose program is controlled by the 4 extra-function calculator keys. Standard chips are now available for statistics, mathematics, metric conversion and surveying. Sharp Electronics Corp., 10 Keystone Pl., Paramus, NJ 07652. Phone(201)265-5600.

Circle No. 188

UNDER-$90 FUNCTION GENERATOR COVERS 1 Hz TO 1 MHz. Sine, triangle or square waves at levels from 0 to 20V p-p, plus TL-compatible square wave and 4V p-p triangle wave outputs, are provided. Output impedance is ≈ 600Ω and sine wave distortion is <2% from 1 Hz to 100 kHz. $89.95. Advanced Electronics, Box 63, 63 Lincoln St., Newton, MA 02161. Phone(617)969-5331.

Circle No. 189

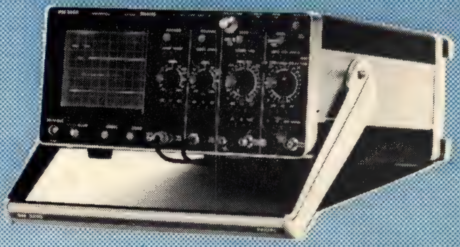
SELF-CONTAINED UNIVERSAL TESTER HANDLES 20 TESTS/SEC. Model UCT-128 functions like a computer-controlled system, yet can be operated by virtually untrained personnel. Three switches provide tester control, and a 16-character alphanumeric display annunciates the test results. No teletypewriter is required. Field reprogrammable ROM's are used for ease and economy of circuit test revising. $10,000, up. General Engineering & Mfg. Corp., 7347 Monticello, Skokie, IL 60076. Phone(312)677-8770.

Circle No. 190

Choose your bandwidth.... TAKE YOUR CHOICE!

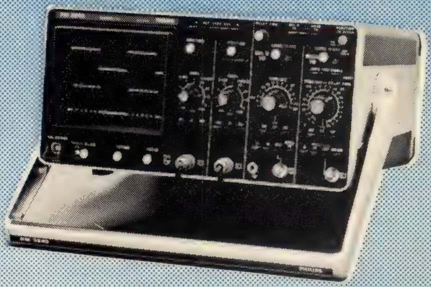
120 MHz/5 mV
- Dual trace/Delaying sweep
- Lightweight: 19.5 lbs
- Bright 20 KV 8 x 10 cm display
- Low 45 Watt power consumption
- X - Y capability
- Easy to use delayed sweep

PM3260E . . . . . $ 1850.00



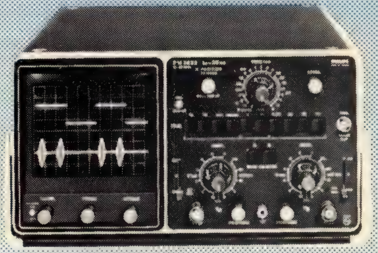
50 MHz/ 5 mV
- Dual trace/Delaying sweep
- Lightweight: 18.5 lbs.
- Bright 10 KV 8 x 10 cm display
- Low 23 Watt power consumption
- X - Y capability
- Easy to use delayed sweep

PM3240 . . . . . $ 1470.00

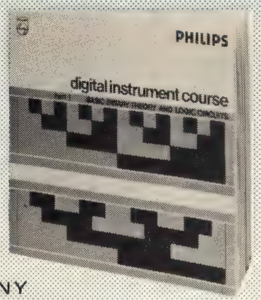


10 MHz/2 mV
- Dual beam to avoid chop/alternate problems
- Brilliant 10 KV 8 x 10 cm display
- Lightweight: 21 lbs.
- TV sync
- X - Y capability

PM3232 . . . . . $ 875.00
PM3233 . . . . . $ 925.00



FREE DIGITAL INSTRUMENT COURSE
In-depth information on digital circuits and the mathematical theory behind them. Number theory, Boolean algebra. The course progresses through digital block, data communication and control. This digital instrument course is yours **FREE**, if you allow one of our Sales Engineers to demonstrate Philips equipment to you. Ask our Field Engineer about your complimentary gift during your demonstration.



For further information, contact:
Philips Test & Measuring Instruments, Inc.
A NORTH AMERICAN PHILIPS COMPANY

400 Crossways Park Drive Woodbury, New York 11797
Telephone: (516) 921-8880 Twx: 510 221 2120

SPECIAL APPLICATIONS INFORMATION 'HOT LINE'
DIAL TOLL FREE NUMBER (800) 645-3043 NEW YORK STATE, CALL COLLECT (516) 921-8880

PHILIPS

For a demonstration Circle No. 21 **For More Information Circle No. 22**

BULL'S-EYE!

Hit the target everytime ... with subminiature monolithic ceramic capacitors from Centre Engineering. A complete line of high quality subminiature monolithic ceramic capacitors are available including; multi-layer chip capacitors, polymer coated leaded devices, multiple capacitor banks, and glass sealed devices. Over 40 different formulations.

Technological advancements in engineering and manufacturing ceramic capacitors in volume have made Centre Engineering an excellent source of supply.

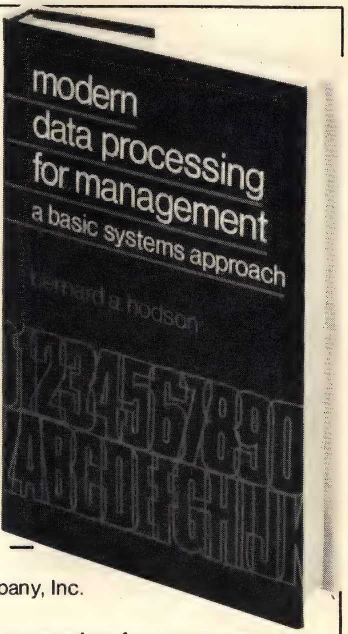
Hit the bull's-eye with Centre Engineering.

Write for additional information.

CENTRE ENGINEERING
2820 E. COLLEGE AVE., STATE COLLEGE, PA 16801
814—237-0321 • TWX 510—691-2634

For more information, Circle No. 23

Orients Management to Systems Analysis



This book, **modern data processing for management, a basic systems approach**, by B. D. Hodson, introduces you to systems analysis, data banks, and computers, and explains the role they can play in your organization. Written in layman's terms for the non-technical manager, it outlines both present and potential applications of computer hardware and software in today's industry. Appendices. Index.

Topics covered in detail include: modern tools for the systems analyst, systems implementation, the creation and use of data banks, management information systems, techniques of data handling, real-time, the computer systems and company networks, the economics of computers, controlling and auditing, the organizational impact of computing, and the future of computing. 318 pp.

Cahners Books, A Division of Cahners Publishing Company, Inc.
89 Franklin Street, Boston, Massachusetts 02110

Please send me ______ copy(ies) of **modern data processing for management, a basic systems approach** at $17.50 each. If not satisfied, I may return the book(s) within 15 days for full refund.

☐ Enclosed is my check for $______ (Publisher pays postage)
☐ Please bill company P.O. #________
☐ Charge to my Master Charge Account Number ☐☐☐☐________
Name________
Company________
Address________
City/State/Zip________
Signature________

Massachusetts residents add 3% Sales Tax

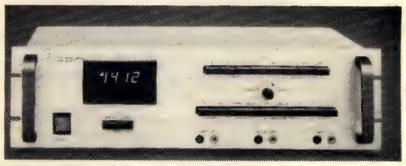
S58/MO10801

EQUIPMENT

LOGIC PROBE FEATURES SELECTABLE THRESHOLD LEVELS. The hand-held Model 1500 tests TTL and CMOS logic, but can be supplied with other threshold levels for RTL, DTL, HTL or other logic. It detects and indicates single pulses as narrow as 10 nsec and pulse trains at frequencies as high as 50 MHz. Input impedance is >2 MΩ. Overload protected for ±250V (dc or ac), the 1500 has reverse-polarity protection to 50V. Alert Technology, Inc., 2901 MacArthur Blvd., Northbrook, IL 60062. Phone(312)498-0940. **Circle No. 191**

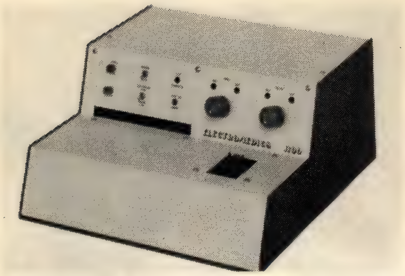
DPM WITH 6000 COUNT CLAIMS 0.08% 90-DAY ACCURACY. Model 3362 has full 1 through 5 readout in the first position. Conversion time is 60 msec max. and the internally controlled repetitive read rate (4/sec) may be increased to 8 via an external shunt resistor. Voltage ranges are 600 mV, 6V and 60V with input resistance of 1000 MΩ, 1000 MΩ and 10 MΩ, respectively. $189. Data Technology Corp., 2700 S. Fairview, Santa Ana, CA 92704. Phone(714)546-7160.

Circle No. 192



DIGITAL ELECTRONIC SWEEP FEATURES STEPLESS RAMPS. Three stepless noise-free ramp functions are provided by the WS-8-10D: single ramp, repetitive triangle and repetitive sawtooth. Each can be pre-set to any of 8 sweep rates from 0.5 to 100 min. The unit features 2 sweep ranges (0 to ±0.2 or ±2V); digital readout of sweep output or % of sweep output on either range; digital signals for interfacing to computer analyzers and analog signals for interfacing to recorders; and automatic sweep centering to return sweep to zero output. Walker Scientific, Inc., Rockdale St., Worcester, MA 01606. Phone(617)852-3674.

Circle No. 193

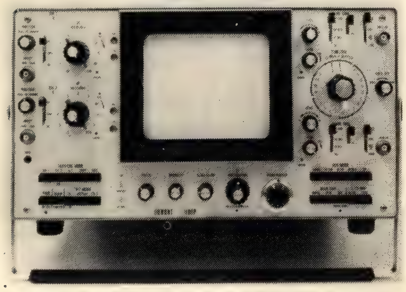


DIGITAL IC TESTERS PERFORM 100% FUNCTIONAL TESTING. Models 1000 and 1100 test DTL, TTL, and CMOS devices. Programmable cards and simple go/no-go fault indicators eliminate operator training or error. High productivity is assured by <1/10-sec cycle times. There are expandable options for testing 24- and 40-pin devices. Model 1000 provides pass/fail testing capability, while Model 1100 incorporates failure-analysis indicators. Prices begin at $550. Electromedics, 3295 Brookdale Dr., Santa Clara, CA 95051. Phone(408)243-3119.

Circle No. 194

SC TESTER PERFORMS BOTH IN- AND OUT-OF-CIRCUIT TESTS. The pocket-size, self-contained Model 215 can check npn and pnp transistors FET's, diodes, SCR's and unijunctions. It instantly and automatically determines proper lead configuration and indicates by LED displays whether the SC is good or bad. Hickok Electrical Instrument Co., 10514 Dupont Ave., Cleveland, OH 44108. Phone(216)541-8060.

Circle No. 195



DUAL-CHANNEL SCOPE FEATURES ELECTRONIC SWITCHING. Portable Model 1100P has vertical sensitivity to 5 mV/cm, a dc-to-100 MHz frequency response and sweep speeds to 5 nsec/cm. The operating modes include CH 1, CH 2, ALT, CHOP, ADD, MAIN, INT, DLYD, MIXED, and calibrated X-Y. Pushbuttons have single functions. $1895 (includes two probes and front cover). Dumont Oscilloscope Labs, Inc., 40 Fairfield Pl., West Caldwell, NJ 07006. Phone(201)575-8666.

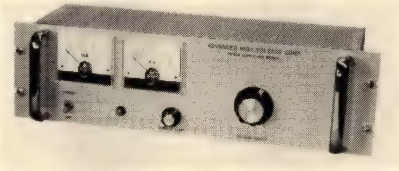
Circle No. 196

TIME-BASE CALIBRATOR SPANS 100 mSEC TO 100 nSEC. Model 900 generates 11 waveforms with a period from 100 msec to 100 nsec, accurate to 0.05%. It produces a TTL-compatible square wave (nominal 0-5V) capable of driving 50Ω. $99. Dialectronics, Inc., 9 Hadley Rd., Lexington, MA 02173. Phone(617)862-3661.

Circle No. 197

ALL-ELECTRONIC HUMIDITY METER READS ACCURATELY IN SECONDS. Hand-held, the "Humi-Chek" is particularly well suited for use by EDP supervisors or service specialists. Its range is from 20 to 90%, with accuracy of 2% and repeatability of 1%. To operate, you simply balance and read the thumbwheel. A standard 9V transistor radio battery powers the device. Beckman Instruments, Inc., Cedar Grove Operations, 89 Commerce Rd., Cedar Grove, NJ 07009.

Circle No. 198



H.V. SUPPLIES DELIVER EITHER CONSTANT VOLTAGE OR CURRENT. Automatic cross-over between modes, plus continuously adjustable voltage and current limits, gives the ARR-series units 2-in-1 usefulness. Besides overload protection, they offer a complete constant-current supply. Featured are full-time voltage and current meters and 10-turn voltage adjustment. The series has 6 models rated from 3 kV at 10 mA to 30 kV at 1 mA. They are 5-1/4 in. high and fit a 19-in. rack. From $495. Advanced High Voltage Co., Inc., 14532 Arminta Ave., Van Nuys, CA 91402. Phone (213)997-7222.

Circle No. 199

DIT-MCO:
The Difference In
Testing

SYSTEM 823

A computer-controlled ultra high speed wiring analyzer system for rapid validation of interconnect systems such as computer backplanes, multilayer boards, cable networks, wired racks, etc.

Proven Solid State Switching

Distributed switching and control eliminates the need for massive adaptor cables and is customized to plug directly into your product or access fixture.

Test Parameters

A wide range of substantially superior test parameters insures more consistent, reliable and accurate testing under a variety of conditions.

Test Speed

System 823 is unequaled in test speed and accuracy. Solid state switching and higher test stimuli enable extremely fast and precise insulation and continuity testing — up to several thousand tests per second.

Test At Higher Voltage

High voltage solid state switching permits testing at 24-volt levels. Higher test stimuli result in more reliable error reporting and isolation of real and potential defects.

Software

System 823 comes complete with a standard software package furnished and maintained by DIT-MCO.

The basic set of hardware and software items may be complemented with a large variety of standard and special options.

CALL OR WRITE . . .
We'll send you our new System 823 literature or ask for a DIT-MCO representative to show you how a System 823 relates to your test needs. He'll show you how to perform tests faster, more simply, and save money too!

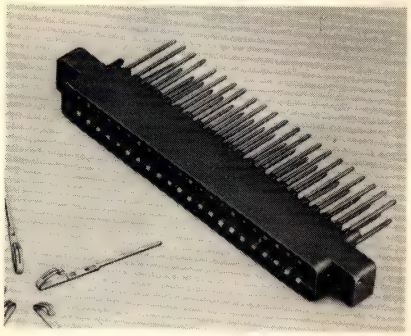
DIT MCO

DIT-MCO INTERNATIONAL
A Division of Xebec Corporation
5612 Brighton Terrace, K. C., Mo. 64130
Telephone (816) 363-6288
Telex Number 42-6149

European Technical Representative, Radix House,
Central Trading Estate, Staines, Middlesex,
TW18-4-XA, England, Telephone (0784) 51444
Telex Number 935023

For more information, Circle No. 25

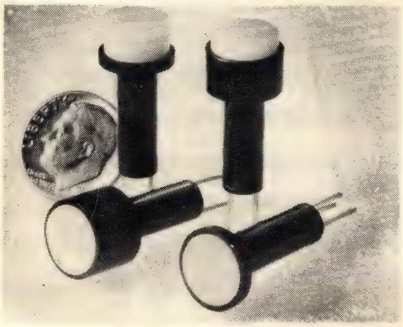
COMPONENTS/MATERIALS



CARD-EDGE CONNECTOR CUTS COST BY USING CA 725 ALLOY. For double-sided 0.062±0.008-in. thick pc boards with contact paths on either 0.1- or 0.125-in. centers, AMP economy wrap connectors are offered with from 6 to 50 contacts. Selectively plated gold protects the critical contact areas, giving 12 mΩ max. contact resistance and 3A current rating. AMP Inc., Harrisburg, PA 17105. Phone(717)564-0101. **Circle No. 200**

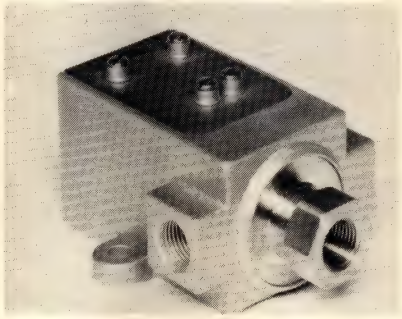
ECCOL^{R} IMPREGNATED CAPACITORS CUT ENVIRONMENTAL POLLUTION. Without using polychlorinated biphenyl impregnant, these ac capacitors exhibit essentially identical electrical performance characteristics. Even the size of ECCOL Capacitors is similar to previous designs, except for a slight increase in case height. Units are available with capacitance values from 1 to 55 μF, with 4 voltage ratings from 300 to 660V ac. Sprague Electric Co., North Adams, MA 01247. Phone(413)664-4411.

Circle No. 201

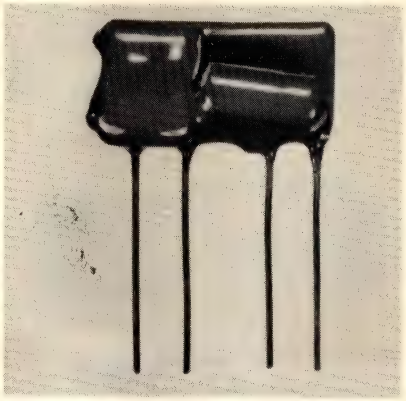


LARGE LENS, HIGH BRIGHTNESS MAKE LED LAMPS EASY TO VIEW. The 460 series offers green, yellow, amber or red LED's, with clear or translucent lenses in any of the 4 colors, or water clear. They mount in 1/4-in. dia. holes and can be positioned on 1/2-in. centers. All have wire-wrap, gold-plated terminals and are available from 2-28V at currents from 9-35 mA. $1.45(100). Data Display Products, 5428 W. 104th St., Los Angeles, CA 90045. Phone(213)641-1232.

Circle No. 202

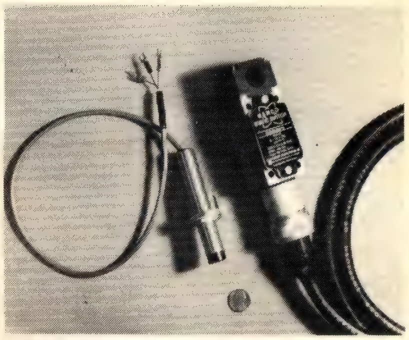


ACCURATE PRESSURE TRANSDUCER GIVES 5V OUTPUT, DRAWS <1/2W. Model GS-102 operates from any dc input voltage between 9 and 15V and provides a F.S. output of 0-5V dc. Total input required is 30 mA max. The terminal error band accuracy of the Model GS-102 is ±1% of F.S., and temperatures from −20 to +180°F produce < ±1% change in F.S. output. Gulton Industries, Inc., 1644 Whittier Ave., Costa Mesa, CA 92627. Phone(714)642-2400. **Circle No. 203**



SMALL BUT ACCURATE TIMER READILY MOUNTS ON PC BOARD. The ICSO-TIMER provides adjustable time delays from 0.1 to 300 sec. It is an all solid-state hybrid network capable of switching standard relays and contactors, and has accuracy of ±2%; fixed conditions. Available input voltages are 115 or 24V ac, 130 or 24V dc. The Icsotimer measures 1.1-in.L×0.6-in.W×0.3-in.H. $5 (in quantity). Instrumentation & Control Systems, Inc., 129 Laura Dr., Addison, IL 60101. Phone(312)543-6200.

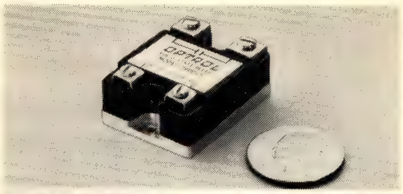
Circle No. 204



S.S. NONCONTACT STATIC SWITCHES BOAST 1000 Hz RATE. The dc-operated Series EE540 and EE510 switches are solid-state alternatives to electromechanical limit switches for position and presence sensing in a variety of dc circuit applications. Cable lengths of up to 1000 ft are practical. Input is 8 to 18V dc, and the output circuit is an open-collector transistor with V_{CEO} of +40V max. Sensing range is fixed at a nominal 0.22 in. Namco Controls, 170 E. 131st St., Cleveland, OH 44108. Phone(216)268-4200. **Circle No. 205**

TINY MOS CHIP CAPACITORS OFFER COMPATIBLE BONDING. Highly stable, the type 15K and 16K Oxsil chip capacitors feature −55 to +150°C operation, high insulation resistance and very high Q. TC is only 35 ppm/°C. Standard capacitance values for the type 15K (single-section) ranges from 1 to 100 pF at 50 WV dc. Multiple-section Type 16K permits capacitance values between 0.5 and 31.5 pF in 0.5 pF steps or between 1 pF and 63 pF in 1 pF steps with stitch bonding of appropriate sections. Sprague Electric Co., Marshall St., North Adams, MA 01247. Phone(413)664-4411.

Circle No. 206

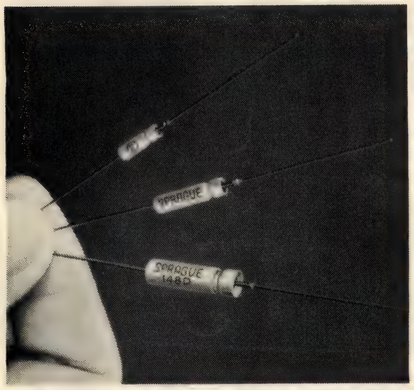


RATINGS TO 45A AND 480V MAKE SS RELAYS STAND OUT. Available with ratings of 3, 5, 10, 25 and 45A and 120, 240 or 480V, these feature twin power SCR's with built-in snubbers in all ratings. They provide high current-surge rating and cooler operation, and eliminate lock-on. Both inductive and resistive loads are handled well. Optical coupling gives input/output isolation. Standard package dimensions are 1-3/4×2-1/4×7/8 in. Optrol, Inc., 5842 Research Dr., Huntington Beach, CA 92649. Phone-(714)892-3313. **Circle No. 207**

SINGLE-COMPONENT ENGINEERING ADHESIVE CURES QUICKLY. DYMAX 801 cures at room temperature to the same strength as heat-cured, two-component adhesives—and eliminates mixing and measuring. It bonds similar and dissimilar materials, including common metals, woods, ceramics and most plastics. Handling strength develops in <2 min., with full cure in <2 hr. Specialty Chemicals Div., MPB Corp., Box 1303, New Britain, CT 06051.

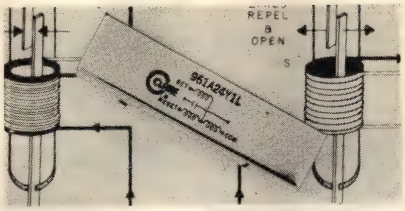
Circle No. 208

WIDE DELAY RANGE IS AVAILABLE IN DELAY-ON-BREAK SS TIMERS. DBO-series models provide fixed or adjustable time delays ranging between 0.1 and 1800 sec, 18 different time ranges and repeat accuracy up to 1%. They are offered with 11 standard input voltages, spdt or dpdt output, contacts rated at 10A and with knob adjustment or locking shaft. They weigh only 8 oz., but are fully protected against power-line transients and withstand 15G shock for a full second. Master Electronic Controls, Box 25662, Los Angeles, CA 90025. Phone(213)393-3177. **Circle No. 209**



HERMETIC SEALING ENHANCES SINTERED-ANODE CAPACITORS. Type 148D sintered-anode Tantalex^{R} capacitors are housed in miniature silver cases. They have true glass-to-tantalum hermetic sealing and are rated for continuous operation from −55 to +85°C (to +125°C with appropriate voltage derating). Voltage ratings range from 6 to 75V dc, and capacitances from 1 to 470 μF are offered. Sprague Electric Co., North Adams, MA 01247. Phone(413)664-4411.

Circle No. 210

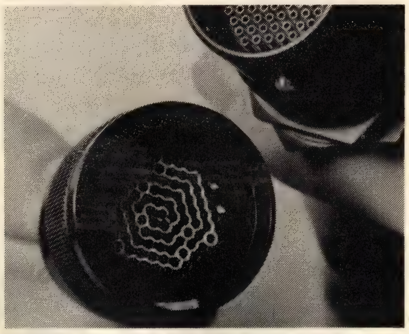


SELF-LATCHING DRY REED RELAYS STAY OPEN OR CLOSED W/O POWER. Remanent-reed blades inside the relay's switch capsule accept like or unlike magnetic polarities which are induced by applied drive pulses. Once pulsed into a set or reset state, the relay remains in that state until the opposite mode is selected. The 961 series contains 1 through 6 pole configurations with 0.150×1.600-in. grid mounting. All feature 1.5-msec set and 1-msec reset times, and 5-VA contact ratings. $5.50 to $12. C.P. Clare & Co., 3101 W. Pratt Ave., Chicago, IL 60645. Phone(312)262-7700.

Circle No. 211

SINGLE-DIGIT 3/8-IN. LED DISPLAY WORKS ON 5 mA/SEG. The FND357 has each of the 7 segments and the decimal point illuminated by a single GaAsP common-anode LED via light-pipe assembly. Its light output averages 0.6 mcd at 20 mA and viewing angle is approximately 60°. All digits are sorted by intensity classifications. Lead spacing, pinouts, and package dimensions are the same as on the FND70. Fairchild Camera & Instrument Corp., 464 Ellis St., Mt. View, CA 94042. Phone(415)962-3816.

Circle No. 212



TWIST-PIN CONTACTS, 0.065-IN. SPACING ENHANCE CONNECTOR. A high contact-density circular connector, the MD 73, uses center-to-center spacing of only 0.065-in. Presently available is a shell size #15 with 91 contacts, but #9-27 contacts, #12-61 contacts, and #18-151 contacts can be had on request. Contacts handle 5A, with sea-level working voltage of 1000V rms. Wire size is #22-24-26 gauge. Samples are available 8 weeks ARO. Malco., 220 Pasadena Ave., S. Pasadena, CA 91030. Phone(213)682-3351. **Circle No. 213**

New INTERNATIONAL **broadband amplifier**

MODEL 150-299

14 db gain—10 to 1,000 MHz

International's inline amplifier provides 14 db gain flat within 1 db over a range of 10 to 1,000 MHz. Impedance 50 ohms. Requires 20 VDC @ 50 ma. For increased gain additional amplifier may be added. Uses BNC type terminals.

SPECIFICATIONS

Range
10 to 1,000 MHz

Impedance
50 ohms

DC Input*
20 VDC 50 ma

Gain**
14 db

Flatness
± 1 db (Ref. 500 MHz)

Operating Temperature
−25 to +70°C

Noise Figure
9 db

VSWR Output
2.0

Output capability for −60 db near intermodulation distortion
100 MV

*Will operate 12 to 24 VDC with some loss in characteristics.
**May cascade for additional gain with consideration of noise and flatness.

Price **$40.00** plus postage
Write for complete catalog.

INTERNATIONAL
CRYSTAL MFG. CO., INC.
10 North Lee
Oklahoma City, Oklahoma 73102
405 236-3741

For more information, Circle No. 26

The revealing truth about DIGITAL FILTERS

Shocking? Well, hardly. But very definitely informative. Reader reviews of this 6-part series were wildly enthusiastic.

So much so that we now offer REPRINTS—a bound collection of the whole series. A ready, convenient and exhaustive reference on an interesting and challenging topic. Order yours today. Check or money order **must** accompany order.

46 pages $3.50 postpaid

(cut along dotted line)

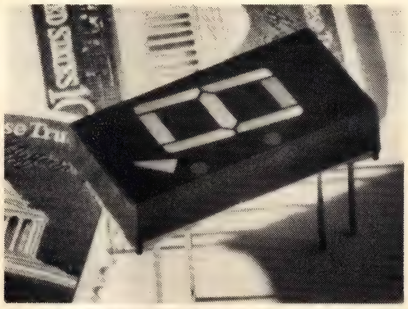
EDN

Digital Filter Series
221 Columbus Ave.
Boston, MA 02116

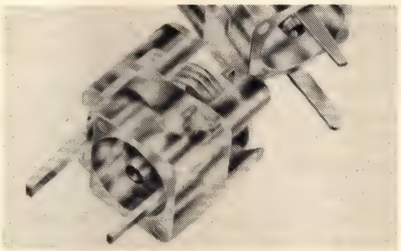
Please send me________ copies of Designers' Guide to Digital Filters @ $3.50 each. Payment enclosed. Make checks payable to EDN.

Quantity	0-9 $3.50
Rates	10-99 $2.95
	100 up $2.75

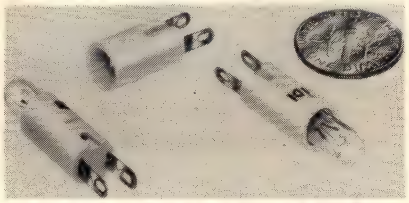
Name________________
Company______________
Address_______________
City__________________
State/ZIP______________
MA residents add 3% Sales Tax



EASILY READ LED DISPLAYS COME IN CHOICE OF 4 COLORS. The MAN 4000-series 0.4-in. digits come in red, yellow, orange or green, and feature a high readability font. A "gappy" appearance is avoided by the beveled shape of the segment corners. Segment brightness at 20 mA dc runs 500, 2000, 300 and 1200 mcd, respectively, for green, orange, red and yellow. $4.20 (1-99). Monsanto Co., Electronics Div., 3400 Hillview Ave., Palo Alto, CA 94304. Phone(415)493-3300. **Circle No. 214**



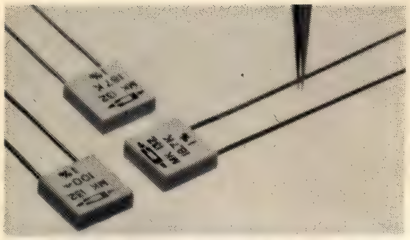
RUGGED PTFE-DIELECTRIC TRIMMERS OFFER STABILITY. Series 809-05 film trimmers with overall size of 0.26×0.3×0.36-in. have contacts arranged for direct insertion in 0.1-in. grid pc boards. They will not crack or drift and feature operation at ambient temperatures as high as 125°C. Capacitance values from 1 to 18 pF are available. Mepco/Electra, Inc., Columbia Rd., Morristown, NJ 07960. Phone(201)539-2000. **Circle No. 215**



NO-FLOAT SOCKETS ACCEPT SUB-MINIATURE WEDGE-BASE LAMPS. The 4100-series sockets provide contact with the lamp regardless of lead position. The lamp is held securely and cannot "float." Either wire leads (Series 4100) or solder terminals (Series 4110) is offered. Savings of over 50% are claimed, compared to conventional sub-miniature flange base or bi-pin base type socket assemblies. Industrial Devices Inc., Edgewater, NJ 07020. Phone(212)867-9700. **Circle No. 216**

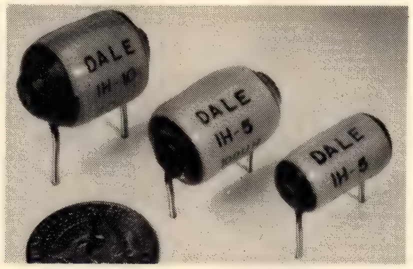
COMPACT, STABLE METAL-OXIDE RESISTORS HANDLE H.V. The thick-film, flat substrate SLIM-MOX^R resistors boast a voltage coefficient of better than 5 ppm/V and full-load drift of <0.5% in 1000 hr. at 70°C (typ.). The TCR is 250 ppm or less to 5000 MΩ. Power rating is 2W@70°C. Standard resistance values of 1, 2, 5, 10, 20, 50, 100, 200, 500, 1000, 2000, and 5000 MΩ (±15%) are available from stock. Nominal overall dimensions are 1×0.5×0.095 in. Victoreen Instrument Div., Sheller-Globe Corp., 10101 Woodland Ave., Cleveland, OH 44104. Phone(216)795-8200. **Circle No. 217**

PRECISION TEMPERATURE SWITCH HAS WIDE OPERATING RANGE. This tiny solid-state unit operates between −30 and +50°C (−22 and +122°F). Its actuation temperature (±0.1°C) can be programmed by an external resistor. Operating like a temperature-actuated thyristor, the device switches from very high to very low resistance at programmable transition temperatures. Features include high reliability, symmetrical switching and direct ac line operation. 40¢ (1000 or less). Multi-State Devices Ltd., 1330 Trans-Canada Hwy., Dorval, Quebec H9P 1H8, Canada. **Circle No. 218**



TINY PRECISION POWER FILM RESISTOR DISSIPATE 0.75W. Model MK 132 resistors use high-stability Micronox resistance films. They handle the full 0.75W at 125°C—yet are housed in a standard CKO6 rectangular package that is only 0.3-in. square and 0.1-in. thick. Available values run from 10Ω to 5 MΩ at 1% tolerance. Maximum working voltage is 400V and the TC is only 50 ppm/°C to ±105°C. Extra-low inductance fits them for high-frequency use. 47¢ to 61¢ (1000). Caddock Electronics, Inc., 3127 Chicago Ave., Riverside, CA 92507. Phone(714)683-5361. **Circle No. 219**

IRRADIATED WIRE INSULATION STANDS SOLDERING-IRON HEAT. Cables with irradiated PVC inner-conductor insulation are rated at 600V and 105°C, and carry military specifications and UL listing. This cable has superior cut-through resistance, abrasion resistance and crush resistance compared to Teflon^{R}, and is far less costly. A wide range of braids, jackets and inner conductors is available. Alpha Wire Corp., 711 Lidgerwood Ave., Elizabeth, NJ 07207. Phone(201)925-8000. **Circle No. 220**

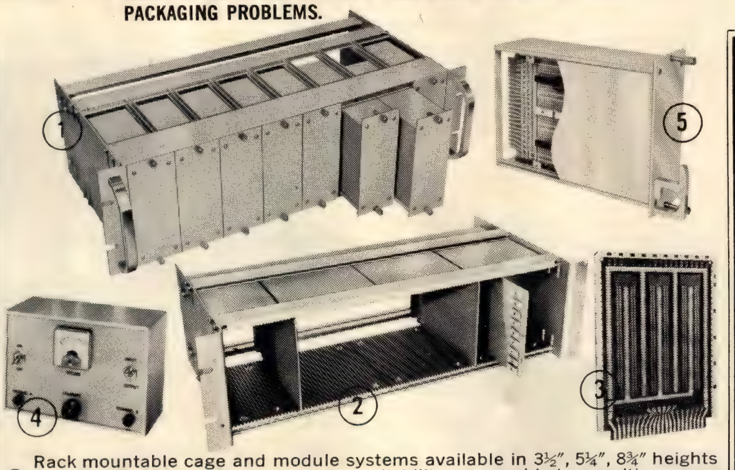


HIGH-CURRENT FILTER CHOKES MOUNT ON PC BOARDS. Models in the IH line have an inductance range from 10 to 100 μh and a current rating to 10A (custom models are available to 20A). All have a flame-retardant coating and pretinned leads. <$1.00 each in quantity. Dale Electronics, Inc., E. Hwy. 50, Yankton, SD 57078. Phone(605)665-9301. **Circle No. 221**

NEW

VECTOR-PAK SYSTEM SOLVES PACKAGING PROBLEMS

- CAGES NOW AVAILABLE FULLY OR PARTIALLY ASSEMBLED.
- NEW EASY-TO-ORDER NUMBERING SYSTEM.
- BUILT IN ADJUSTABILITY AND FLEXIBILITY TO SOLVE YOUR PACKAGING PROBLEMS.



① Rack mountable cage and module systems available in 3½", 5¼", 8¾" heights and 9", 12", 15" depths. Immediate availability—assembled or multi purpose kit versions.
② Rugged Vector Pak Card Cages with extruded ABS or aluminum guides located on .15", .25", or .3" multiples.
③ Dozens of new Plugbords for building Plug-In Cards—IC and discrete types.
④ Multi-Mod Cases—sleek functional aluminum cases for instruments and other circuitry. 4 slotted interior surfaces for cards, mounting plates.
⑤ EFP modules in 1.6", 2", 3", or 4½" widths have slots for cards 4½" x 6½", 2.7" x 6.5", 8" x 9.6", slide off sides

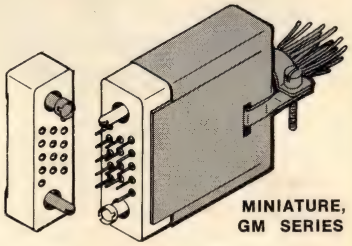
Send for new specification sheets. NIMS bins and modules also available.

VECTOR ELECTRONIC CO., INC.
12460 Gladstone Ave., Sylmar, California 91342
Phone: (213) 365-9661 ▪ TWX (910) 496-1539

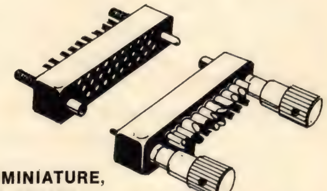
72-2

For more information, Circle No. 28

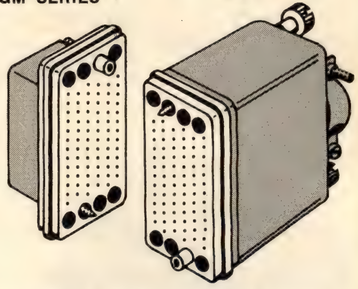
For A Choice Of Rectangular Connectors



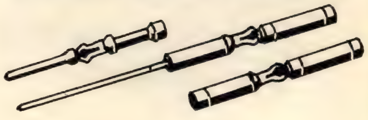
MINIATURE, GM SERIES



SUBMINIATURE, SGM SERIES



REMOVABLE CONTACT, GMCT SERIES



Contact Positronics!

We offer miniature and subminiature connectors for rack and panel applications. Contact configuration range from 5 to 104 contacts. Ampere ratings vary from 3 to 13 amps. Solder, crimp and wire wrap contacts are standard. Insulators are DAP or phenolic. Complete choice of hoods, shells, guides and threadlocks are available.

Our connectors are mateable and interchangeable with competitve makes and conform to Mil. specifications. Delivery: Stock to 4 weeks.

Positronic Industries, Inc.

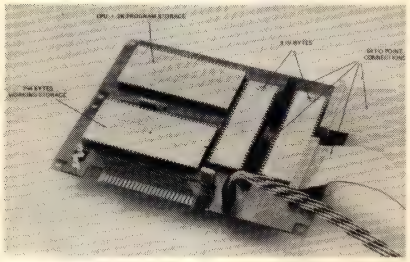
CONNECTOR DIVISION
1906 S. Stewart,
Springfield, Mo. 65804
(417) 883-3434

Representatives and Distributors located in all principal cities.

Send for Catalogs. Samples available for specific applications.

For more information, Circle No. 29

COMPUTER PRODUCTS



MICROCOMPUTER EMPHASIZES I/O CONTROL. The SMS MicroController system executes complete instructions in 300 nsec. Each system includes a CPU, memory (ROM/pROM program storage and RAM working storage) and direct register I/O interface with variable field-address capability. MCMAC, a symbolic program language, enables assembly-level instruction set programming to create firmware. Prices range from $370 for 4.5×4.5-in. system to $1460 for the 6.9×13.5-in. system. Scientific Micro Systems, Inc., 520 Clyde Ave., Mt. View, CA 94043. Phone(415)964-5700.

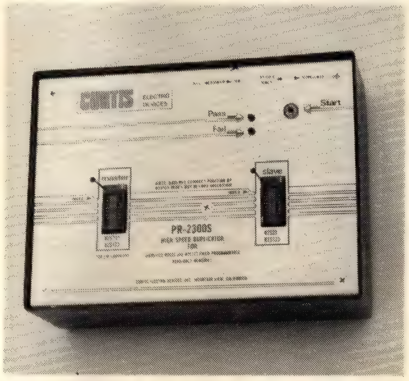
Circle No. 222

PROGRAMMABLE CALCULATORS PUT IT ALL TOGETHER. Series 900 calculators are equipped with a printer, visual display, magnetic-card reader, up to 41 memories and full decision-making capability. The mag cards can be used for program storage or off-line data storage. Packages of special keys with hard-wired functions are available. Model 920-1 is $1695; Model 920-2 is $1995. Rockwell International, 3370 Miraloma Ave., Anaheim, CA 92803. Phone(714)632-1680.

Circle No. 223

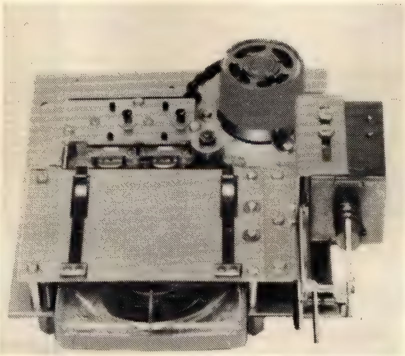
COMPACT COMPUTER GETS DOWN TO BASIC'S. In one console unit, model 2220/2200S combines a CRT display, tape-cassette drive and dual-purpose keyboard. The CPU includes a hard-wired BASIC interpreter and 4k bytes of memory expandable to 16k. The CRT can display 1024 chars. on a 9-in. screen. A standard alphanumeric keyboard is combined with a BASIC keyboard to allow single-stroke statement inputs. Outboard printer optional. $5400. Wang Laboratories, Inc., 836 North St., Tewksbury, MA 01876. Phone(617)851-4111.

Circle No. 224



PRODUCTION PROGRAMMER PROPAGATES PROM'S. The PR-2300S will program Signetics 82S23 and 82S123 Schottky pROM's from a pin-compatible ROM, ROM simulator or computer. Operator inserts blank pROM, pushes START and waits for PASS/FAIL indicator. Average programming time is 1 sec. A "verify-only" function allows checking of unknown devices. Housing is 10×8×4 in., wt. 5 lbs. $499.50. Curtis Electro Devices, Inc., Box 4090, Mt. View, CA 94040. Phone(415)964-3136.

Circle No. 225

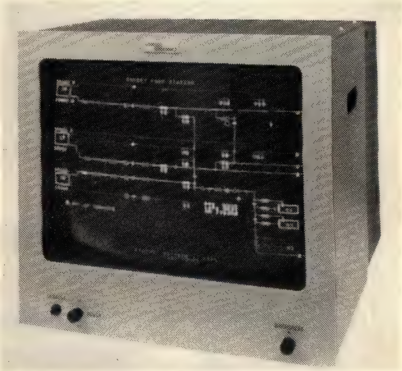


TAPE TRANSPORT DRIVES ENDLESS LOOP. Model A3, utilizing a standard NAB "A" size cartridge, is electrically controlled for remote operation. The unit provides 3 adjustments for 4-point head mounts; a balanced, synchronous capstan motor; and nonmagnetic stainless steel tape guide. A high traction, self-aligning pinch roller with industrial ball bearings eliminates tape-edge wear. $65 (1000). Amilon Corp., 49-12 30th Ave., Woodside, NY 11377. Phone(212)274-1794.

Circle No. 226

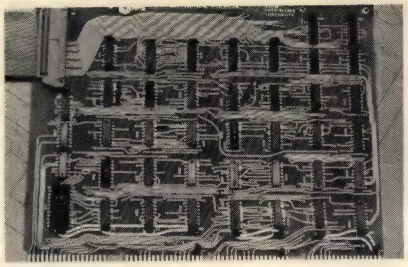
PRINTER ELECTRONICS REDUCE TO SINGLE PC BOARD. Model 301, with an 80-col. line, and Model 501, with a 132-col. line, are serial dot-matrix LSI impact printers that operate at 165 chars./sec. Matrix pattern is 5×7 or 9×7 ASCII char. set. The units will produce 5 copies and have a paper slew rate of 8 ips. A parallel interface is standard. Model 301 is $2275 and 501 is $3315. Centronics Data Computer Corp., Hudson, NH 03051. Phone(603)883-0111.

Circle No. 227



CRT ELIMINATES CONVERGENCE CONTROLS. Model 8020 RGB input raster-scan color monitor is a 100% solid-state unit. This 19-in. diagonal unit can be remotely mounted for process monitoring and control. Video response is flat to 10 MHz. The unit has a resolution of 659 lines max. vertical, with horizontal geometric distortion <1%. Linearity is 1%, and convergence 0.25%, of picture height. $2000. Delivery, 30-60 days ARO. Aydin Controls, 414 Commerce Dr., Ft. Washington, PA 19034. Phone(215)542-7800.

Circle No. 228

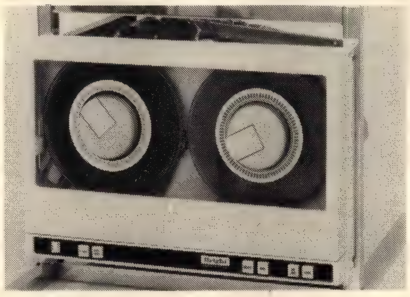


UNIVERSAL CARD-READER CONTROLLER SERVES PDP-8/E. The universal controller CRC-8E will interface most TTL compatible mark-sense and punched-card readers, while maintaining software compatibility. The 10-min. installation requires no modifications to existing hardware. The unit provides asynchronous operation to full reader speed. $850. Delivery is off-the-shelf to 4 wks. Applied Peripheral Systems, Inc., 1781 Barcelona St., Livermore, CA 94550. Phone(415)443-7077.

Circle No. 229

PLUG-IN CARD TROUBLESHOOTS TAPE DRIVES. The TC-12 transport exerciser plugs directly into the I/O connector of all Digi-Data 7 or 9 track, NRZI or phase encoded transports. Controls provide read/write forward/reverse action during continuous, start/stop, or shuttling tape motion. All I/O lines can be observed at labelled test points. $125. Digi-Data Corp., 8580 Dorsey Run Rd., Jessup, MD 20794. Phone(301)498-0200.

Circle No. 230

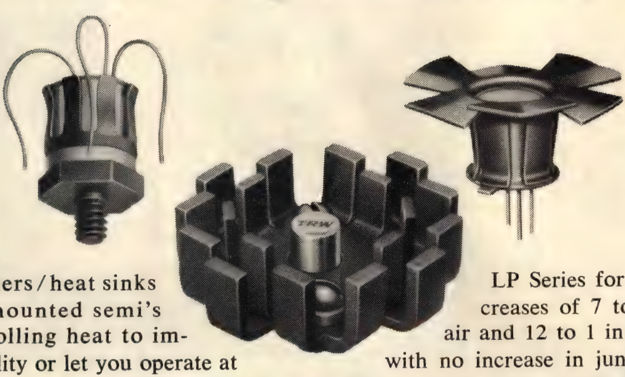


MAG-TAPE DRIVE OPERATES UNDER ADVERSE CONDITIONS. Model 2630 handles 8-1/2-in. IBM compatible reels in either NRZI or phase-encoded formats. Bit density can be 1600, 800, 555 or 200 bpi with tape speed of 12.5 to 37.5 ips. This portable unit has an industry compatible interface. $3375. Bright Industries, 686 W. Maude Ave., Sunnyvale, CA 94086. Phone(415)321-2133.

Circle No. 231

No. 21 of a Series

Now get a firm grip on your lead-mounted semi's and heat problems, too



IERC retainers/heat sinks hold lead-mounted semi's while controlling heat to improve reliability or let you operate at higher power levels. Our TXB's for Mil-spec environments are excellent retainers on p-c boards or serve as efficient thermal links between case and heat sink. BeO washers are available for electrically-hot-case applications. Use our staggered-finger LP Series for power increases of 7 to 1 in still air and 12 to 1 in forced air with no increase in junction temperature. And, if your semi's are already mounted, slip on a Fan Top and get higher wattages for just pennies. Send for catalog. IERC, 135 W. Magnolia Blvd., Burbank, Calif. 91502, a subsidiary of Dynamics Corporation of America.

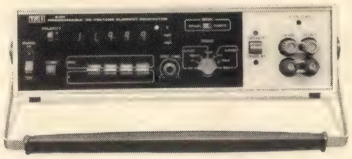
IERC DCA **Heat Sinks**

For more information, Circle No. 30

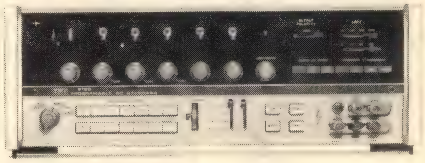
A bench and system use innovator from T.R.I.

New

Model: 6141
Programmable DC V/I Generator



Model: 6120 Programmable DC Standard



Two DC V/I Generators for all new applications

1. A stimulus to auto testing equipment...Programmable functions for OEM use.

Two DC V/I generators can control externally the functions you need for OEM applications. These units have a pulse-width modulation system, so switching output noise is far less than that of conventional products.

2. Includes a 14-step memory and flip switch for newer, wider bench uses.

Model 6120 includes a 14-step memory so it can be used as a simple testing device for storage of the desired output. Model 6141 has a new flip switch enabling quick setting of the output.

3. High accuracy and very small step advantages permitting use as a standard device.

Both models have very small step advantages, continuously variable, and highly stabilized output for adequate use as standard device.

4. Continuous function highly suited for instrumentation checks and maintenance.

Both models can vary the output level both stepwise and continuously, making them highly suited for checking and maintenace.

	Model 6141	Model 6120
DCV	0~ ±12 V (1μV step)	0~ ±1200 V (1μV step)
DCI	0~ ±120 mA (0.1μA step)	0~ ±120 mA (0.1μA step)
Price	$890	$2995

TRI

T.R.I. Corporation
505 West Olive Avenue Sunnyvale, CA 94086
(408) 733-9080

For more information, Circle No. 27

CRT TERMINALS WEIGH IN AT UNDER 10 LBS. These portable data terminals replace, or operate with, Model 33 Teletypes. Model 209 features a 40 chars./line by 16-line display format, while Model 33 has an 80×16 display. Teletype current loop, TTL or EIA RS-232 interfaces are standard. Data rates are 110 and 300 baud with optional built-in coupler or up to 9600 baud hardwired. Model 209 is $1195; Model 33 is $1295. Digi-Log Systems, Inc., Babylon Rd., Horsham, PA 19044. Phone(215)672-0800.

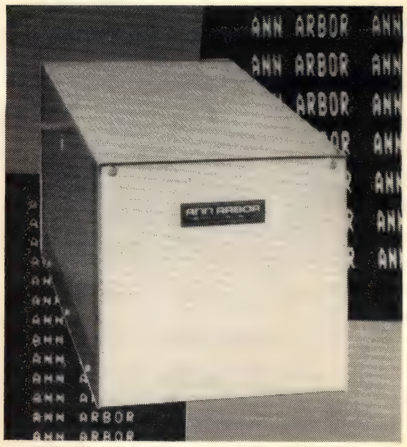
Circle No. 232

DUAL-DRIVE FLOPPY FEATURES MASTER/SLAVE UNITS. Model 74M master drive interfaces directly to the user's equipment with full electronics. The 74S slave drive contains min. electronics and connects to a secondary interface on the 74M. Up to 3 74S units can be daisy-chained onto a 74M. Both IBM-compatible units offer unformatted capacity of 3.1 M-bits/disc, 250 bps transfer rate and 6 msec track-to-track access time. The 74M costs $695; the 74S, $595. Orbis Systems, Inc., 3303 Harbor Blvd., Bldg. K4, Costa Mesa, CA 92626. Phone(714)556-8450.

Circle No. 233

PRINTER SYSTEM COMBINES SPEED AND RELIABILITY. Using 36 chars. on the drum, Model M470U prints at 1800 lpm. A full 64-char. set yields a print speed of 1250 lpm. Both modes produce a full 132-col. format and handle multi-part forms. The impact printer is completely plug-compatible with the UNIVAC Model 418 III, 494 and 1100-series computers. Macro Products Corp., 3110 E. Willow St., Long Beach, CA 90806. Phone(213)595-6337.

Circle No. 234



SELECTABLE DISPLAY FORMAT ADDS VERSATILITY TO CRT. Models 1632 (Read Only) and KSR (CRT) terminals allow users to select either 512 standard size or 256 double height chars. In addition, blink, intensity and reverse video are available. Standard features include switch-selectable page and roll modes. Data rate is 110 to 9600 baud. Price ranges from $740 to $1890 with delivery from stock to 60 days. Ann Arbor Terminals, Inc., 6107 Jackson Rd., Ann Arbor, MI 48103. Phone(313)769-0926.

Circle No. 235

Our waterproof switch assemblies fit your requirements. No matter how unusual.

We probably have a waterproof switch assembly to fit your most critical requirement. Even if you've already completed your prototype.

What's more, our waterproof switch assemblies are based on our own basic waterproof switches, all of which meet MIL-S-13484 and MS-39058. They include toggle, push-button, lever, cam followers, special mounting brackets, and are designed for either manual or automatic operation.

You can specify these assemblies in a selection of shapes and a variety of materials, including tough plastics, special stainless steels, as well as other materials.

Send for full data. Control Products, Inc., 280 Ridgedale Ave., E. Hanover, N.J. 07936.

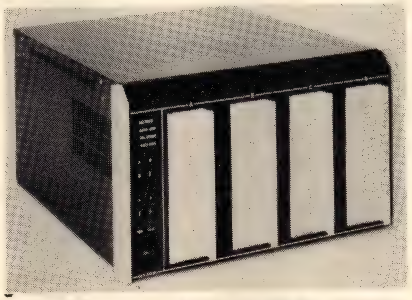
CPI
Specialists in Switching

For more information, Circle No. 31

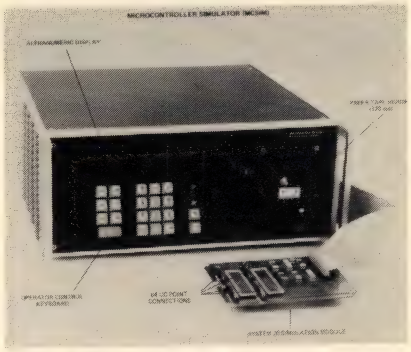
TRANSFORMERS
AUDIO POWER
NEW!
PLUG-IN PC POWER
•
TELEPHONE COUPLING
•
DC-DC CONVERTER
•
STUDIO BROADCAST
•
REQUEST NEW CATALOG # 741
COMMERCIAL/MIL
COMPLETE LINE OF STOCK TRANSFORMERS
IMMEDIATE DELIVERY FROM DISTRIBUTORS
MICROTRAN COMPANY, INC.
145 E. Mineola Ave., Valley Stream, N.Y. 11582

For more information, Circle No. 32

PRINTER OCCUPIES LESS SPACE THAN A TYPEWRITER. Model 180 offers a print rate of 180 lpm using a 10×12 dot matrix available in multiple ASCII fonts. The printing technique is a dry-ink transfer process using an endless mag-tape loop. This quiet printer will also produce graphs, curve plots and bar charts at on-line speeds to 2400 baud. Under $3000 (OEM quan.). Delivery is 60 days ARO. Inforex, Inc., 21 North Ave., Burlington, MA 01830. Phone(617)272-6470. **Circle No. 236**

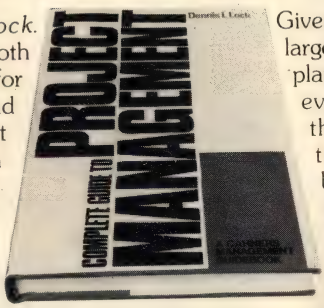


FOUR-PACK FLOPPY DRIVE OFFERS PROGRAMMABLE FORMATTER. The AED 3100-P provides 1 to 4 disc drives and all electronics in a single cabinet. Each drive can read or write in a different format and store 128,128 sixteen-bit words in an IBM 3740 format. Access is 10 msec/track with a 66.7 μsec/word transfer rate. The heads load in 20 msec. A full range of interfaces are available. $2040. Delivery is 30 days. Advanced Electronics Design, Inc., 754 N. Pastoria St., Sunnyvale, CA 94086. Phone (408) 733-3555. **Circle No. 237**



MICROCOMPUTER SIMULATOR EASES FIRMWARE DESIGN. MCSIM provides total product simulation of the SMS MicroController. It is a real-time on-line replica with front panel controls for program modification and control during delay. MCSIM plugs into the user's system exactly as the SMS MicroController does and has an identical (electrical, physical and logical) I/O structure. Scientific Micro Systems, Inc., 520 Clyde Ave., Mt. View, CA 94043. Phone(415)964-5700.

Circle No. 238


Dennis L. Lock
COMPLETE GUIDE TO PROJECT MANAGEMENT
A CAHNERS MANAGEMENT HANDBOOK

Complete Guide to PROJECT MANAGEMENT

Dennis L. Lock. Gives techniques adaptable to both large and small companies for planning, costing, controlling, and evaluating a project, so that they can be completed on time and to specs and budget. CMP and PERT are explained and their application made clear. Costs are talked about in depth, with a thorough discussion of the effects of delays and modifications. Essential reading for anyone on either the technical or managerial side of industry dealing in project management. Over 60 how-to-do-it illustrations; many practical examples. 6 x 9 224 pp.

S58/MO10801

Cahners Books, A Division of Cahners Publishing Co., Inc.
89 Franklin Street, Boston, Massachusetts 02110

Please send me ______copy(ies) of *Complete Guide to Project Management* at $10.95 each. If not satisfied, I may return the book(s) within 15 days for full refund.

☐ Enclosed is my check for $______(Publisher pays postage.)
☐ Please bill
Name______________________________
Address____________________ Phone__________
City/State/Zip______________________________
Signature______________________________
Massachusetts residents add 3% sales tax

SEASTROM
MANUFACTURING CO., INC.
Product Specialists in . . .
ELECTRICAL/ELECTRONIC HARDWARE
SPRING CLIPS, WASHERS - ALL TYPES
MILITARY STANDARDS

SEASTROM OFFERS ITS ALL NEW COMPREHENSIVE CATALOG #40B. This 250 page catalog features the company's full range of products in a colorful book specially indexed for ready reference.

FREE

Including such items as . . .

- Flat Round Washers—Metallic
- Flat Round Washers—Non-Metallic
- Spring Washers
- Shoulder Washers
- Tab & Notch Washers
- Washers—Miscellaneous Configurations
- Expansion Plugs
- Military Standards
- Clamps & Brackets
- Spring Clips
- Solder Lugs
- Solid State Insulators
- Bus Bars, Terminal Blocks & Insulating Strips
- Miscellaneous Electrical/Electronic Hardware/Tags
- Sheet Metal Nuts & Strips
- Engineering Tables, Materials & Finish Specifications
- Numerical & Alphabetical Index of Parts

No need to design it . . . you will undoubtedly find it in Seastrom's Catalog all stocked for immediate delivery . . . write to

SEASTROM
MANUFACTURING CO., INC.
701 SONORA AVE., DEPT. H-2-5
GLENDALE, CALIF. 91201
(213) 245-9121 • TWX 910-497-2271

For more information, Circle No. 33

CIRCUITS

SAMPLE/HOLD REQUIRES ONLY AN EXTERNAL HOLDING CAPACITOR. The SHM-IC-1 consists of a differential input amp., a digitally controlled electronic switch and a buffer amp. In the unity-gain noninverting configuration, the device has a ±10V input and output range with $10^8\Omega$ input impedance. The holding capacitor may be selected to give the desired speed and accuracy. Power required is ±15V at 5 mA max. $29. Datel Systems, Inc., 1020 Turnpike St., Canton, MA 02021. Phone(617)828-8000.

Circle No. 239

AMPLIFIER OFFERS HIGH POWER OUT AND HIGH INTERCEPT POINT. The WJ-A9 thin-film cascadable amplifier has a power output of +22 dBm and intercept point of +35 dBm. The unit provides 11 dB of gain anywhere in the frequency range of 5 to 500 MHz, and operates with supply voltages from +15 to +24V dc. Performance vs. changing supply voltage is typified by an output power spec that varies from +22 dBm at 24V to +18 dBm at 15V. $125. Watkins-Johnson Co., 3333 Hillview Ave., Palo Alto, CA 94304. Phone(415)493-4141.

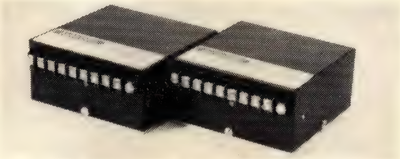
Circle No. 240

V/F CONVERTER PROVIDES 5 DECADES OF DYNAMIC RANGE. Model 4707 delivers a 100-Hz to 5.05-MHz pulse-train output that is a direct linear function of a +1 mV to +10V dc input signal. It features linearity of 0.004%, 44 ppm/°C drift, and a differential linearity of 14-16 bits. The current-input pin can be used for direct conversion of current to frequency, with 0.45 mA being nominal F.S. $149. Teledyne Philbrick, Allied Dr., Dedham, MA 02026. Phone(617)329-1600.

Circle No. 241

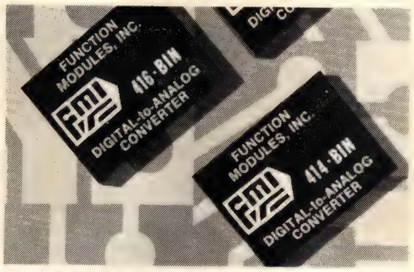
PRESSURE TRANSDUCERS FEATURE HIGH ACCURACY, HIGH PRECISION. Series LX3700 (19 models) includes gage, absolute and differential units in 8 pressure ranges (from −15 to +15 to 0 to +100 psi). All have a 10V dc output-voltage span, and typ. specs include: accuracy, ±0.75% of span; stability, better than ±0.25% of span; TC, better than ±0.005% of span/°C. LX3800 series (8 models) includes absolute and gage units with pressure ranges from −15 to +15 to 0 to +30 psi. $66.67 (100). National Semiconductor Corp., 2900 Semiconductor Dr., Santa Clara, CA 95051. Phone(408)732-5000.

Circle No. 242



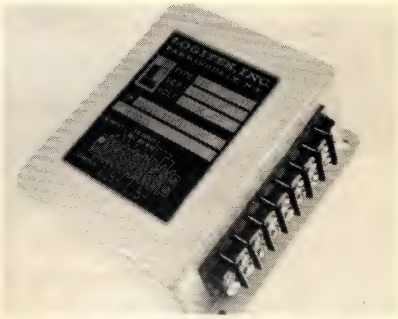
HIGH-EFFICIENCY DC/DC CONVERTERS PROLONG BATTERY LIFE. The G4-25 series has 6 standard 25W models, with outputs of 5, 6, 12, 15, 24 and 28V dc. 24V input is standard, but 28 and 48V options are available. Line and load regulation are 0.5% and 2.0%, respectively. These converters, with efficiencies to 75%, have ripple deviation of <0.5% of the output voltage. Conduction cooled, the units operate over the range of −20 to +71°C. $175. Aaron-Davis Co., Inc., 1720 22nd St., Santa Monica, CA 90404. Phone (213)829-1834.

Circle No. 243



D/A CONVERTER FAMILY OFFERS LOW DRIFT AND LOW COST. Family lineup is: 414-BIN 14-bit binary, 416-BIN 16-bit binary, 416-BCD 4-digit BCD and 418-BCD 4-1/2-digit BCD. Circuit stability is reflected by TC's of ±3, ±2, ±3 and ±3 ppm/°C, respectively. Except for the 418, all models can be connected for current or voltage outputs, and either unipolar or bipolar operation (except BCD models). $149(414-BIN), $175(416-BIN), $159(416-BCD), $195(418-BCD). Function Modules, Inc., 711 W. 17th St., Costa Mesa, CA 92626. Phone(714)645-6001.

Circle No. 244

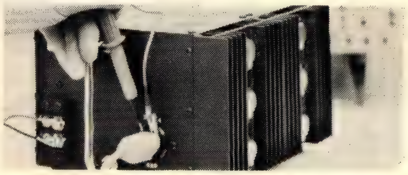


DC VOLTAGE SENSOR PROVIDES ALARM AND POWER DISCONNECT. Type EDA is powered by 50, 60 or 400 Hz from 110 to 480V ac, and it can be set from 4-200V dc. Accuracy is ±1% and hysteresis is <1%. The circuit design precludes false triggering due to line-voltage transients. It includes integral time delays (factory settable from 250 msec to 10 sec) to prevent nuisance trips. The 10A output relay operates when the dc voltage level is within the preset band. Logitek, Inc., 42 Central Ave., Farmingdale, NY 11735. Phone(516)694-3080.

Circle No. 245

SYNCHRO/SINE-COSINE CONVERTER EMPHASIZES HIGH ACCURACY. The ST300 transforms either a 3-wire synchro or 4-wire resolver input to a pair of dc outputs proportional to the sine and cosine of the synchro shaft angle. Overall static conversion accuracy is ±3′ of arc, max. Dynamic lag error is 5 arc-sec/rpm. Units deliver an output level of ±10V dc, and require power of ±15V dc at 20 mA. $190. C & A Products, Inc., 37-12 58th St., Woodside, NY 11377. Phone(212)779-4303.

Circle No. 246



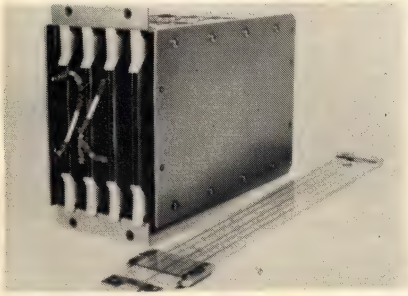
DC/SINE WAVE INVERTER SATISFIES HIGH POWER REQUIREMENTS. Model KN3T-115-60 operates from an input voltage of 11-15V dc, and delivers output power of 30 VA. Output voltage is 115V ac ±2%, at 60 ±2 Hz with 5% distortion max. Line and load regulation are 3%. The unit has surge capability of up to 3 times rated output power. It can withstand input transients of 45V dc for 0.1 sec, and is overload protected by a magnetic type circuit breaker. $239. Abbott Transistor Laboratories, Inc., 5200 W. Jefferson Blvd., Los Angeles, CA 90016. Phone(213)936-8185.

Circle No. 247

SAMPLE/HOLD DELIVERS SUPERIOR PERFORMANCE AT LOW PRICE. The MP240 features low aperture uncertainty (jitter of ±1 nsec), high transfer accuracy (within ±0.01% of specified gain of 1), high linearity (±0.005% FSR), low signal feedthrough in the hold mode (−90 dB) and a fast acquisition time (5 μsec to acquire a 10V step within 0.01%). The unit is functionally complete, and provides the capability for external trimming to accomodate system offsets. $39 (100). Analogic Corp., Audubon Rd., Wakefield, MA 01880. Phone(617)246-0300. **Circle No. 248**

FET OP AMP COMBINES HIGH PERFORMANCE WITH LOW COST. The 9737 amplifier features ±600V/μsec min. slew rate and a min. gain bandwidth product of 70 MHz. High performance is reflected by specs such as 10 pA max. bias current, and noise voltage of 30 nV/$\sqrt{Hz}$ max. It will swing ±10V into a 500Ω load. Nominal supply requirement is ±15V, but operation is guaranteed from ±8 to ±20V. $45. Optical Electronics, Inc. Box 11140, Tucson, AZ 85734. Phone(602)624-8358.

Circle No. 249



VIDEO DIGITIZER ALLOWS CONVERSION RATES TO 17 MHz. Model VADC-8/17, containing an integral sample/hold, features aperture jitter of <60 psec and aperture delay of 37 nsec. The output delivers parallel positive true offset binary logic compatible with ECL/TTL. Offset and gain TC's are ±400 μV/°C and ±100 ppm/°C, respectively, in the operating temperature range of 0 to 70°C. $3500. ILC Data Device Corp., 105 Wilbur Pl., Bohemia, NY 11716. Phone(516)567-5600.

Circle No. 250

When it comes to one-source savings on solid-state power relays...

COME TO CRYDOM...

We're first with the most of the best!

After all, we originated and patented (#3,723,769) what has become the industry standard for solid-state power relays. Of course, we make the broadest line, available, 20 models, all in the same field-proven package. What's more, they're UL recognized and CSA certified. And since you can satisfy every application need from one source, you'll simplify procurement, lower expenses.

So, whenever you need to control rugged AC loads from low voltage ICs or AC line voltage signals, you're sure to quickly find the most appropriate and reliable solution with the leader — Crydom.

LINE VOLTAGE (VAC)	FULL-LOAD CURRENT RATING (AMPS)					
	2.5	8	10	12	25	40
120	D1202 A1202		D1210 A1210		D1225 A1225	D1240 A1240
240	D2402 A2402		D2410 A2410		D2425 A2425	D2440 A2440
480		D4808 A4808		D4812 A4812		

CONTROL VOLTAGES: D PREFIX — 3-32VDC/A PREFIX — 90-280VAC

Call your local Crydom authorized distributor for off-the-shelf deliveries of any of our 20 models. And, when you need production quantities in a hurry, contact us at the factory for all the facts.

CRYDOM CONTROLS IOR
DIVISION OF INTERNATIONAL RECTIFIER
1521 Grand Ave., El Segundo, California 90245 · (213) 322-4987

For more information, Circle No. 38

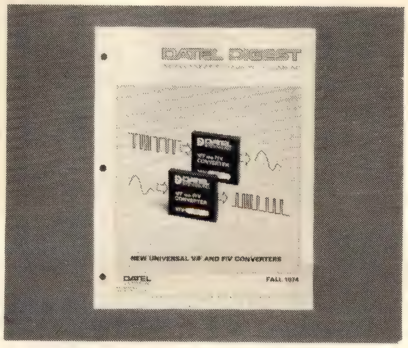
POWDER METALLURGY. The design and performance capabilities of powder metallurgy are described in a 24-pg., illustrated booklet. Engineering information is provided for such P/M materials as carbon-steel, copper-steel, nickel-silver, brass, bronze, aluminum and magnetic materials. Properties covered include density/porosity, permeability, strength, ductility, hardness, corrosion resistance, surface finish and sound damping. $3. MPIF, Box 2054, Princeton, NJ 08540.
INQUIRE DIRECT.

MOTION CONTROL. A design/applications guide presents solutions to motion-control problems in the computer-peripheral and business-machines fields. Twelve applications show how clutches and brakes, step motors, ball screws, and high helix screws have successfully been applied to solve incremental control problems. Warner Electric Brake & Clutch Co., 449 Gardner St., Beloit, WI 53511. **Circle No. 252**

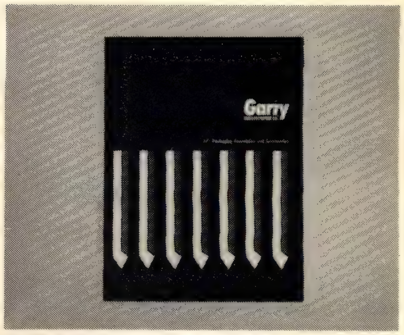
THE ANATOMY OF A COMPILER. The 2nd edition starts with a comprehensive review of the concepts of computer language translation and then proceeds to develop rules to compose the syntax of complex languages. This 464-pg. book also describes techniques and algorithms for efficiently generating arithmetic expressions and Polish strings. $17.95. Van Nostrand Reinhold Co., 450 W. 33rd St., New York, NY 10001.
INQUIRE DIRECT.

SOCKET LOGIC CARDS BROCHURE contains mechanical specifications and basic card dimensions, as well as details on some associated packaging hardware for these Socket Logic Cambi-cards^{R}. Cambridge Thermionic Corp., 445 Concord Ave., Cambridge, MA 02138.
Circle No. 254

TOOLS AND SAFETY EQUIPMENT for professional use are described in an illustrated, 80-pg. catalog. It is organized for easy reference and fully indexed—both alphabetically and by product number. Mathias Klein & Sons, Inc., 7200 McCormick Rd., Chicago, IL 60645.
Circle No. 255



PRODUCT DIGEST. A new quarterly publication, the Datel Digest, features summaries of significant new products. This 8-pg. premier issue discusses V/F converters, DPM's, ADC's, DAC's and sample/hold circuits. Descriptions, specs., block diagrams and other information useful to the design engineer are included. Datel Systems, Inc., 1020 Turnpike St., Canton, MA 02021.
Circle No. 256



IC PACKAGING ASSEMBLIES. The company's 1975 catalog features IC packaging assemblies and accessories, with particular emphasis on modular wire-wrapped circuit boards. Several new products, among them a product line designed for pluggable wire-wrap packaging of high-speed ECL logic, are included. Garry Mfg. Co., 1010 Jersey Ave., New Brunswick, NJ 08902.
Circle No. 257

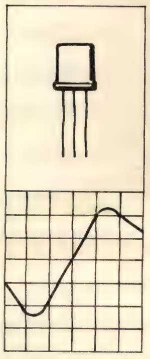
SOLID-STATE LOGIC. Bulletin 1720 covers the CARDLOK series. It illustrates with both pictures and words how solid-state input/output devices perform, and how they can be used to convert ac/dc pilot device voltages to logic levels. The colorful 8-pg. brochure also lists the type of card racks and power supplies available in the CARDLOK system. Catalog Service Dept., Industrial Controls Div., Allen-Bradley Co., Milwaukee, WI 53204.
Circle No. 258

EXPANDABLE VOICE ANNUNCIATOR for audio readout, with whole words stored in ROM's, is described in a short-form brochure. Application information, block diagrams, package dimensions, timing diagrams and input/output connections, as well as ordering information for the system, are included. Master Specialties Co., 1640 Monrovia Ave., Costa Mesa, CA 92627.
Circle No. 259

"DIGITAL INSTRUMENT COURSE" offers an in-depth understanding of digital circuits and the mathematical theory behind them. The course is divided into 5 areas: basic binary theory and logic circuits; digital timers and counters; digital voltmeters; data logging in small systems; and automatic measuring systems. Part I (60 pgs.) and Part II (64 pgs.) are available for $3.50 ea. NY residents, add 7% tax. Publications Dept., Philips Test & Measuring Instruments, Inc., 400 Crossways Park Dr., Woodbury, NY 11797.
INQUIRE DIRECT.

PTI introduces

First edition monolithic crystal discriminator



Model 2283F, at 10.7 MHz, offers 1% total harmonic distortion and 800 mV of recovered audio when used with CA3089E quadrature detector. Model 2378F offers similar performance at 21.4 MHz. Data sheets available on request.

Specify integrated crystal filters from

Pti

Piezo Technology Inc.
2400 Diversified Way, Orlando, FL 32804, (305) 425-1574

For more information, Circle No. 34

CALCULATOR PERIPHERALS. This brochure lists an assortment of peripheral and interface devices that team with the Monroe 1800 Series calculator. Emphasis is placed on turning the calculator into a microcomputer system complete with software support. Technical Analysis Corp., 120 W. Wieuca Rd., N.E., Atlanta, GA 30342. **Circle No. 263**

RENTAL INSTRUMENTS. This '74-'75 catalog lists over 5000 instruments available for short- or long-term lease; 100 nationwide sales/service centers; ancillary services such as measurement & testing, calibration & maintenance, terminal services, and instrumentation repair & calibration. General Electric Co., Building 28, Room 450, One River Rd., Schenectady, NY 12345. **Circle No. 264**

FULL BASIC COMPILER. This brochure shows how a full BASIC compiler increases the efficiency of Models 100 and 200 of the HP 3000 minicomputer series. Detailed in its 16 pgs. are the model's multilingual and batch capabilities, timesharing, system and data management features as well as the cost effectiveness of both models. Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, CA 94304. **Circle No. 265**

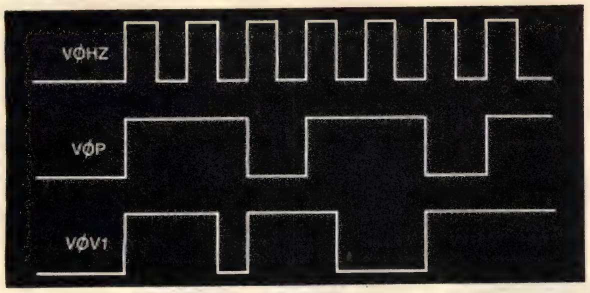
INDUCTIVE DEVICES and custom networks for military, computer and industrial applications are the subject of this 20-pg. brochure. It provides comprehensive specs on molded RF chokes, encapsulated subminature and minature toroidal and variable inductors, wideband transformers, pulse transformers, low-pass, band-pass, high-pass and LC filters. Vanguard Electronics Co., Inc., 930 W. Hyde Park Blvd. Inglewood, CA 90302. **Circle No. 266**

3-D DISPLAYS. A 56-pg. book describes the various applications of 3-D display modules. Discussed are some technical aspects of 3-D displays and generation circuits for various images such as spheres, hourglass images and solid cubes. Psychological, medical and 2-dimensional applications of the 3-D system are included. Optical Electronics, Inc., Box 11140, Tucson, AZ 85734. **Circle No. 267**

SOLDERS. An 8-pg. catalog covers solders, flux-core solders, soldering fluxes, vapor degreasing solvents and special-purpose chemicals. Products described include solderforms, resin core solders, plastic resin core solders, solid-wire solder, pure and mildly activated rosins, foaming resins and organic fluxes. Kester Solder, 4021 Wrightwood Ave., Chicago, IL 60639. **Circle No. 268**

OPERATIONAL POWER SUPPLIES. Eighteen separate groups of power supply/amplifiers, ranging up to 1000W output and up to 5000V, are discussed in a 6-pg. brochure. Kepco, Inc., 131-38 Sanford Ave., Flushing, NY 11352. **Circle No. 269**

Creating Waveshapes to Test Charge Coupled Devices? Digital Arrays?



Serial Parallel Recording and Communications Systems?

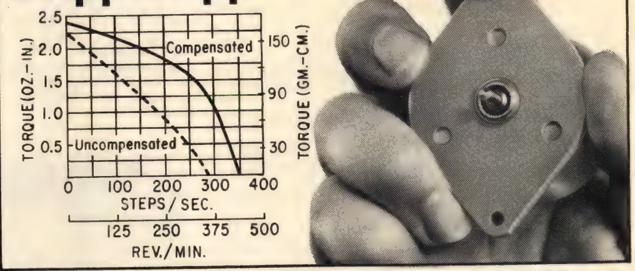
If so, you should know about our MG-3 Word Generator which provides DC to 50 MB/sec serial and parallel data. It works with our other TMI modules to provide:
- Clock Source
- Width/Delay Control
- Amplitude/Offset Control
- Data Modification/Sync Detection

Call collect or write for our magnetic tape and CCD Technology Notes.

tau-tron inc
11 Esquire Road, North Billerica, Mass. 01862 Tel: (617) 667-3874

For more information, Circle No. 36

Discover new performance and economy for your stepper applications.



4-phase PM logic motors for under $9ea.*

Get information today on our new low cost 82401 Series reversible permanent magnet logic stepper motor. It will achieve an optimum cost vs. performance ratio for you. End uses include analytical instrumentation and computer peripheral applications such as printer drives, X-Y plotter drives and chart drives.

Coil design assures low wattage operation......3.5 watts for both 5 vdc and 12 vdc models. Stable stepping operation is achieved by using a permanent magnet construction. Maximum pull-in/out torque is 2.4 oz-in. with a compensation network. Also a maximum pull-in rate of 350 steps/sec and pull-out rate of 480 steps/sec can be attained. Basic step angle is 7.5°, but integral gearing can be furnished to provide a variety of stepping angles and torques.

*In 500 quantities.

Send for information today!

A.W. HAYDON CO. PRODUCTS

NORTH AMERICAN PHILIPS CONTROLS CORP.

Cheshire, Conn. 06410 • (203) 272-0301

For more information, Circle No. 37

LITERATURE

ADDISON AutoTrak
Self-programming FAULT FINDER SYSTEM
for testing—Backplanes, Harnesses, and Cables

FAULT-FINDER SYSTEM. A 6-pg. brochure discusses the AutoTrak, self-programming continuity test system for backplanes, harnesses and cables. Also included is a brief summary of the AutoTrak's various operating controls, error-detection displays and models available. Specific applications for each of the test modes are described in detail. Addison Div. of Muirhead, Inc., 1101 Bristol Rd., Mountainside, NJ 07092.

Circle No. 270

TESTING H.V. POWER SUPPLIES. Bulletin STP-473 describes high-voltage power supply loading methods for both constant and changing load; test set-ups and procedures for voltage calibration; and test set-ups and methods for both static and dynamic output voltage regulation. It also contains instructions for checking output current regulation, ripple, temperature coefficient and stability. Spellman High-Voltage Electronics Corp., 1930 Adee Ave., Bronx, NY 10469. **Circle No. 271**

SOLID-STATE DIP RELAY. Catalog #203 reflects dimensional and packaging changes, more precisely defined test configurations affecting repetitive peak off-state voltage ratings, and a restatement of max. output to a new rating of 140V ac @ 750 mA for the 203 series relay. The folder includes full engineering data, electrical characteristics and drawings that display the relay's mechanical dimensions, circuit schematics and typical applications. C. P. Clare & Co., 3101 W. Pratt Ave., Chicago, IL 60645.

Circle No. 272

CONNECTOR CATALOG. Eight different series of precision electronic connectors for commercial and military applications are listed and highlighted with pertinent specifications for each group. The 16-pg. catalog describes pc, removable contact, rack and panel, center screwlock, power, terminal block, test point and special connector designs. Continental Connector Corp., 34-63 56th St., Woodside, NY 11377. **Circle No. 273**

INTERCONNECTION TESTING. The 17-pg. brochure describes the N151 Interconnection Test System that is designed to test backplanes, bare pc boards and cable assemblies. Testing problems and questions to ask when purchasing a test system are discussed. The brochure also presents the basic hardware of the N151. Teradyne, Inc., 183 Essex St., Boston, MA 02111.

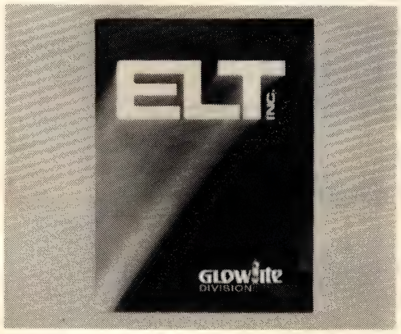
Circle No. 274

TEMPORARY COMPONENT SPACERS. A packaging guide aids in the selection of temporary component-mounting spacers. It lists a complete family of DISS-O-PAD™ wash-away spacers and references them to typical applications. Bivar, Inc., 1617 E. Edinger Ave., Santa Ana, CA 92705. **Circle No. 275**

CHOPPERS AND REED RELAYS. A 32-pg. catalog describes solid-state choppers and reed relays including basic choppers, transformer-isolated choppers, high-frequency choppers, microchoppers, chopper drivers, microreed relays, reed power relays and light-isolated relays. Solid State Electronics Corp., 15321 Rayen St., Sepulveda, CA 91343.

Circle No. 276

CAPACITORS, RELAYS and connector products are discussed in a 60-pg. specification/selection guide. It catalogs the latest data for easy reference by engineers and purchasing agents. The guide also describes 6 new capacitor lines and 2 new types of relays. Arco Electronics, Community Dr., Great Neck, NY 10022. **Circle No. 277**



CIRCUIT COMPONENT LAMPS. An illustrated, 12-pg. catalog on neon indicator and circuit-component lamps will assist design engineers and purchasing agents with lamp specifications and applications. A handy reference section of glow-lamp physical characteristics, term definitions and graphs will help in lamp evaluation. ELT, Inc.,/Glow-Lite Div., Pauls Valley, OK 73075.

Circle No. 278

EDN SALES OFFICES

H. Victor Drumm
Executive Vice President
and Publisher
221 Columbus Ave.
Boston, MA 02116
(617) 536-7780

NEW YORK CITY 10017
Bill Segallis, District Manager
205 E. 42nd St.
(212) 949-4423

BOSTON 02116
Richard Parker, District Manager
Hal Short, District Manager
221 Columbus Ave.
(617) 536-7780

PHILADELPHIA 19103
Steve Farkas, District Manager
Penn Towers
1819 John F. Kennedy Blvd.
(215) 569-2424

CHICAGO 60521
Terry McDermott, Midwest Manager
Frank Sibley, District Manager
15 Spinning Wheel Rd.
Hinsdale, IL 60521
(312) 654-2390

CLEVELAND 44115
Frank Hund, District Manager
Frank Sibley, District Manager
1621 Euclid Ave.
(216) 696-1800

DENVER 80206
John Huff, Regional Manager
270 St. Paul St.
(303) 388-4511

SAN FRANCISCO 95008
Hugh R. Roome, Vice President,
Northwest Manager
Pruneyard Towers
1901 So. Bascom St.
Campbell, CA 95008
(408) 377-6777

LOS ANGELES 90036
Ed Schrader, Regional Manager
5670 Wilshire Blvd.
(213) 933-9525

TOKYO 106 JAPAN
Mr. Chihiro Nagahama,
Managing Director
TRADE MEDIA—IBPA (Japan)
R. 516, Roppongi Uni House
4-3-11, Roppongi, Minato-ku
(03) 585-9571 Telex: J28208

signals and noise

Get square roots the easy way

As an avid reader of EDN Magazine, I have noticed recently that there have been a number of short articles on 4-function calculator utilization. The primary thrust of many of these articles is a technique for calculating $\sqrt{N}$. An example is "Obtaining Accurate Square Roots From Simple Calculators" by A. J. Kauder (EDN—pg. 42—Dec. 5, '74).

I note with interest that, in fact, the vast majority of the techniques are identical, even though the basis of the equation is claimed to be a series expansion, a geometric progression, or a quadratic equation. The essence of this common technique for determining $\sqrt{N}$ is to mentally make a first approximation, A_1, and then use it in a recursive relation wherein the error, $N\text{-}A_1^2$, is calculated and normalized with the factor $2A_1$. This normalized error is then combined with the original approximation to yield a more accurate approximation:

$$A_2 = A_1 + \frac{N - A_1^2}{2A_1}$$

What I find particularly interesting is the variety of cumbersome formulations that are suggested when, in reality, there is one that is quite convenient to use with 4-function calculators. If the above relation is combined over a common denominator it reduces to:

$$A_2 = \frac{A_1^2 + N}{2A_1}$$

In practice, when a value of A_n has been calculated it can be jotted down (or stored in memory) and then, typically, "×" and "=" can be typed without clearing the machine. This (1) shows you the accuracy of your current approximation while, at the same time, (2) performing the first step of the next iteration in case more accuracy is desired. Thus, this approach has a "built in" accuracy check and it minimizes both mental effort and the number of key strokes. Note that any first approximation will yield an accurate answer after five or six iterations but a good first guess will generally require only one iteration.

Yours truly,
Peter McKittrick
Digital Design Dept.
Raytheon Missile Systems Div.
Bedford, MA 01730

A typical reaction

Dear Mr. Cushman,

Thanks for writing an excellent, "down to earth," article on microprocessors (EDN September 20, 1974, pg. 46, "How to get acquainted with a µP"). I'm a senior E.E. major at the University of Texas and our undergraduate program has only one course in general computer structure. I am starved for information on µP's!

Until I read your article, I thought one would have to spend thousands of dollars for various "components" to get actual, hands-on, experience with µP's. Thanks for setting me straight.

Thanks,
Kelly Batlos

I NEED SOMEONE WITH NEW IDEAS; SOMEONE WILLING TO START AT THE BOTTOM; SOMEONE WILLING TO STAY THERE...

Beware of Ma Bell!

Dear Sir:

This letter is in reference to the article "Home-vacation data center" by Robert S. Scott which appeared in the July 20 issue of your publication.

The author suggests that two data terminals could be connected to the phone lines but fails to indicate that if these data sets are customer provided, it's essential that a connecting arrangement should be used.

The connection of customer-provided devices such as this requires that there be this protective connecting arrangement installed by the telephone company, as specified in all state and interstate tariffs.

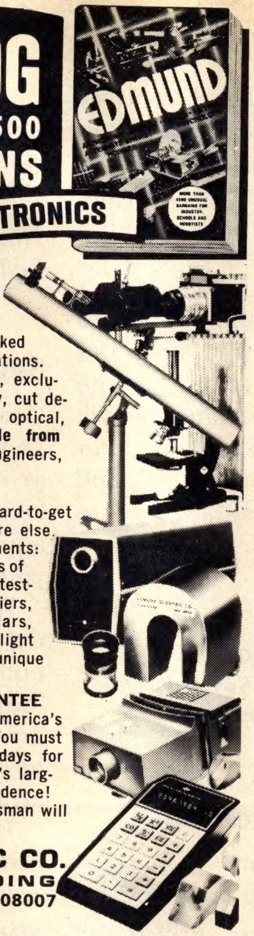
Further, connections to the phone lines should not be made by other than trained telephone company installers to avoid hazardous electrical conditions or service problems.

Special protective connecting arrangements are required by the tariff to prevent service problems for customers which might be caused by sending nonstandard electrical signals into the telephone switching network. And the telephone companies have the responsibility of enforcing all state tariffs which include those for the connection of customer-provided communications devices to the telephone network.

It would be helpful to your readers to inform them that this is a requirement.

Sincerely,

Conrad Pologe
AT&T
New York, NY 10007


EDMUND
MORE THAN 4500 UNUSUAL BARGAINS FOR INDUSTRY, SCHOOLS AND HOBBYISTS

FREE CATALOG
CHOOSE FROM OVER 4,500
UNUSUAL BARGAINS
OPTICS • SCIENCE • ELECTRONICS

1,000's OF HARD-TO-FIND BUYS FOR INDUSTRY
Brand new 180-page easy-to-read edition packed with new products, charts, diagrams, illustrations. On-the-job helps; quality control aids, unique, exclusive items to speed your work, improve quality, cut development and production costs! Loaded with optical, scientific and electronic equipment **available from stock** for industry, research labs, design engineers, experimenters, hobbyists.

ONE SOURCE FOR ALL YOUR NEEDS
Tremendous variety. Terrific savings. Countless hard-to-get surplus bargains. Many "one-of-a-kinds" nowhere else. Ingenious scientific tools. Thousands of components: lenses, prisms, wedges, mirrors, mounts, all types of accessories. Hundreds of instruments: pollution testing equipment, lasers, comparators, magnifiers, microscopes, projectors, telescopes, binoculars, photo attachments, ecological items, black light equipment and America's largest collection of unique lighting products.

BUY DIRECT WITH MONEY-BACK GUARANTEE
Edmund ships over 5,000 orders monthly to America's largest industrials — every item guaranteed! You must be satisfied, or return your purchase in 30 days for your money back. Shop the catalog of America's largest Science-Optics-Electronics Mart with confidence! Get your FREE copy without obligation. No salesman will call. Write now for free catalog. "AT"

EDMUND SCIENTIFIC CO.
300 EDSCORP BUILDING
BARRINGTON, NEW JERSEY 08007
TELEPHONE: 609-547-3488

For more information, Circle No. 41

MINIATURE CIRCUIT BREAKERS

High Quality...
Low Cost...
Dependable Protection

Overcurrent protector, manual reset eliminates fuse replacement. Convenient panel mounting.* 15 fractional ratings from 0.1 to 3 amp. Other models up to 400 amp. Trip-free and fool-proof, UL and CSA approved.

**PC board version available*

For more information please write or call.

E-T-A PRODUCTS CO. OF AMERICA
7400 N. Croname Rd. • Chicago, Ill. 60648 • (312) 647-8303

For more information, Circle No. 42

ADVERTISERS INDEX

Beckman Instruments, Inc.,
Information Displays Operations 6
Bell & Howell, CEC/Instruments Division 46
Berg Electronics CII
Bowmar Instrument Corp. 9
Cahners Books 73
Centre Engineering 64
Control Products Inc. 72
Crydom Controls 75
Digital Equipment Corp. 4-5
DIT-MCO International 65
Dynascan Corp. 40
E-T-A Products Co. of America 80
Edmund Scientific Co. 80
EDN Caravan 52-53
EDN Microprocessor Reprint 56
Electronic Processors Inc. 39
John Fluke Mfg. Co., Ltd. 27
Gates Energy Products, Inc. 3
General Radio 10
Heinemann Electric Co. 2
Hewlett-Packard 12-13
IERC 76
International Crystal Mfg. Co., Inc. 67
Johanson Mfg. Corp. 17
McGill Mfg. Co., Inc. CIII
Micro Switch 19
Microtran Co., Inc. 72
Motorola Semiconductor Products, Inc. 8
Nitron 20
North American Philips Controls Corp. 77
Philips Test &
Measuring Instruments, Inc. 63
Piezo Technology Inc. 76
Positronic Industries, Inc. 69
RCA Solid State CIV
Seastrom Mfg. Co., Inc. 73
Sprague Electric Co. 61
Tau-Tron Inc. 77
T.R.I. Corp. 71
TRW/Cinch Connectors 40
Varo Semiconductor, Inc. 18
Vector Electronic Co., Inc. 69
Woven Electronics 11

WHEN IT COMES TO RELIABILITY, McGILL SWITCHES ARE JEWELS—at popular prices

Finding switches with the right electrical and mechanical characteristics for your applications is usually not too big a problem. But finding switches that assure the most reliable performance is another matter. McGill switches have earned a reputation for high reliability in a variety of types of consumer, commercial and industrial products. And now it's easier than ever to find everything you need right in McGill Catalog 89—toggle, rocker, push-button, snap-action, miniatures, sub-miniatures, actuator styling, and optional features galore that simplify design and assembly.

McGill Manufacturing Company, Inc., Electrical Division,
Valparaiso, Indiana 46383

McGILL®
ENGINEERED SWITCHES

For more information, Circle No. 39

Available from recognized McGill Master Switch Distributors

What's new in MOS...

RCA announces the 7001I memory in volume.

What is the company who created CMOS doing in NMOS memories? Putting all of its knowledge in "P" and "N" MOS technologies and its experience in high volume manufacture to work to become an important new source to you.

You told us that although there is already a long list of memory makers you could use another major supplier. One from whom you could expect a steady flow of product in volume. For as long as you need it. Without having to stop to worry about quality problems.

When we decided to enter the field and make memories an important part of the broad RCA semiconductor line, we chose the 7001I 1024-Bit RAM as our starting point. Less than six months after that decision we can accept orders for quantities as high as you can use. And by the time you need 4K memories, we expect to be ready to make the same high volume-high quality offer.

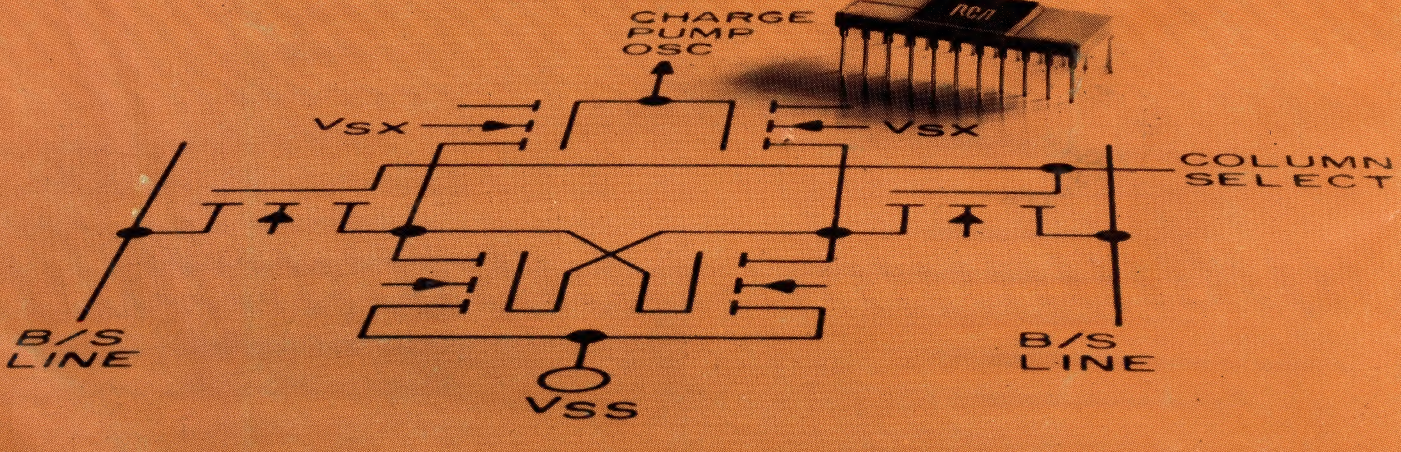
In speed, cycle time, TTL compatibility, package, and every other way the RCA MW7001ID is interchangeable with any industry standard 7001I. So when the need is there, RCA is ready. We're anxious to set up a program to help you evaluate our product and our production capability.

If you prefer to check out the MW7001ID on your own, you can purchase evaluation quantities through your RCA Solid State distributor. If you really have no immediate need for a new high quality source for the 7001I, watch for the NMOS announcements forthcoming from RCA. When it comes to memories, we're planning to be able to help you in more ways than one.

Write: RCA Solid State. Box 3200, Somerville, New Jersey 08876; Ste. Anne de Bellevue 810, Canada; Sunbury-on-Thames, U.K.; Fuji Bldg., Tokyo, Japan.

RCA

For more information, Circle No. 40



RCA. The first house in CMOS moves into memories.